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Description

Background of the Invention

This invention relates to self-contained gas powered surgical staplers and more particularly to a self-contained surgical stapler which is powered by relatively low pressure gas and which is therefore adaptable for manufacture as a disposable item. Although the invention will be illustrated and described in its application to skin and fascia type surgical staplers, it will be understood that the principles of the invention are applicable to other surgical stapler type instruments such as ligating and dividing instruments in which staple-like elements are advanced and formed as part of the operation of the instrument.

Self-contained gas powered surgical staplers are known, as shown, for example, in U.S. patents 3,618,842; 3,643,851; 3,662,939; 3,717,294; 3,815,476; and 3,837,555. Typically, these staplers include a replaceable cylinder which supplies gas (e.g., carbon dioxide or nitrogen) at relatively high pressure (e.g., 800 p.s.i.g.) for powering the instrument. The high pressure gas used in these staplers requires that the staplers be of relatively heavy construction which can safely accommodate the high pressures involved. Because of their construction, these instruments are relatively expensive to manufacture. These instruments are therefore generally intended to be relatively permanent and reusable.

A hand-actuated surgical stapler is shown in WO—A—80/00230. This stapler comprises a linkage mechanism that provides increasing mechanical advantage as the stapling stroke advances.

Any reusable surgical instrument must be cleaned and sterilized between uses. Cleaning is time consuming and may require disassembly of the instrument with the consequent possibility of damage to the instrument. Sterilization requires expensive sterilization equipment. The trend is therefore increasingly toward instruments which have lower initial cost than permanent instruments, are sterile when purchased, and are disposable after a single use so that cleaning and sterilization costs are avoided.

It is accordingly an object of this invention to provide a self-contained gas powered surgical stapler which can be economically manufactured and safely handled as a disposable item.

Use of a relatively low pressure gas is advantageous to enable a stapler to be made of lighter construction and less expensive materials. This is desirable to lower the cost and make the stapler economically disposable. The stapler must, however, be capable of generating the substantial forces required to form the staples. Typically, the staples are metal wire which is partially formed prior to use and which must be further formed (e.g., bent around or crimped against an anvil) by the stapler. To generate the relatively large forces required to form the staples with low pressure gas would ordinarily require a relatively large pneumatic actuator. This is undesirable because a large actuator makes the stapler bulky and difficult to work with. In addition, a large actuator unnecessarily consumes a large amount of gas during the portion of actuator motion when relatively large forces are not required, i.e., during the first part of the actuator stroke when the staple is merely being advanced to the staple forming position. The gas which is thus effectively wasted substantially reduces the number of stapling operations which can be performed by the stapler before its gas supply is exhausted. This substantially shortens the useful life of the stapler if the gas supply is not replaceable, and even if the gas supply is replaceable, it undesirably increases the frequency with which the gas supply must be replaced.

It is therefore another object of this invention to provide a self-contained gas powered stapler which employs low pressure gas without the necessity for a large pneumatic actuator and which makes efficient use of the gas supply to increase the number of stapling operations which can be performed before the gas supply is exhausted.

Summary of the Invention

These and other objects of the invention are accomplished in accordance with the principles of the invention by providing a stapler having a mechanical linkage between a relatively low pressure pneumatic actuator and the staple driving element for matching the force available from the pneumatic actuator to the force required during various portions of the stroke of the staple driving element. The mechanical linkage provides a relatively low force during the first portion of the stroke of the staple driving element as is sufficient for advancing a staple to the staple forming position. Thereafter, the mechanical linkage provides the relatively large force required for forming the staple.

The mechanical linkage comprises a four bar linkage disposed in a plane parallel to the translational axis of the staple driver and having a first hinge connection attached to the staple driver, an opposite second hinge connection fixed at a point on an axis through the first hinge connection parallel to the translational axis of the staple driver, and third and fourth hinge connections respectively spaced on opposite sides of the axis through the first and second hinge connections; and cam means connected to the pneumatic piston and having first and second cam surfaces for respectively operating on the third and fourth hinge connections to push the third and fourth hinge connections substantially parallel to the translational axis of the staple driver during a first portion of the driving stroke of the pneumatic piston corresponding to the advance of the staple and to push the third and fourth hinge connections toward one another during the remainder of the driving stroke of the pneumatic piston corresponding to forming the staple.

During the initial staple advancing portion of the staple driving stroke, the mechanical linkage preferably amplifies the motion of the pneumatic

actuator so that the relatively large motion required to advance the staple can be provided by relatively small motion of the actuator. This helps reduce the required length of the actuator stroke and therefore helps reduce the length of the actuator. During the subsequent staple forming portion of the staple driving stroke, the mechanical linkage preferably amplifies the force produced by the pneumatic actuator so that a relatively small diameter actuator can be used with low pressure gas.

Throughout the stroke of the apparatus, the mechanical linkage substantially matches the force required to the force available from the pneumatic actuator. Accordingly, a substantially constant force available from the pneumatic actuator throughout its stroke is converted by the mechanical linkage to the substantially different forces required during the various portions of the stroke of the staple driving element. The pneumatic energy expended during each stroke of the apparatus is therefore not substantially greater than the mechanical work required during that stroke, and the gas supply is used more efficiently to increase the number of stapling operations available from a given quantity of gas.

The stapler of this invention is preferably controlled by a manually operable trigger or other similar control. Momentary operation of the control initiates an operating cycle of the stapler which normally is automatically completed without continued actuation of the control. Preferably the stapler performs only one operating cycle in response to each operation of the control regardless of the length of time the control is operated beyond the time required to initiate an operating cycle. The stapler also cannot begin a new operating cycle until the preceding cycle is complete. In a particularly preferred embodiment of the inventiom, the operating cycle can be aborted after it has begun by another operation of the control.

Further features of the invention, its nature and various advantages will be more apparent from the accompanying drawing and the following detailed description of the invention.

Brief Description of the Drawing

Figure 1 is a partly exploded overall perspective view of an illustrative embodiment of the surgical stapler of this invention with portions of the housing cut away to reveal the interior of the apparatus.

Figure 2 is a perspective view showing how the stapler of Figure 1 is held and operated in use.

Figure 3 is a sectional view of the stapler of Figure 1 prior to the start of a stapler operating cycle.

Figures 4—8 are views similar to Figure 3 showing the condition of the stapler mechanism at various sequential stages in its normal operating cycle.

Figures 9 and 10 are detailed exploded perspective views of two of the parts shown in Figures 3—8.

Figures 11 and 12 are partial perspective views of the apparatus shown in Figures 3—10 showing operation of the apparatus to interrupt an operating cycle of the stapler.

Figure 13 is a sectional view taken along the line 13—13 in Figure 3 and also showing the stapler prior to the start of an operating cycle.

Figures 14 and 15 are views similar to Figure 13 showing the condition of the stapler mechanism at various sequential stages in its operating cycle.

Figure 16 is a force diagram useful in explaining the operation and advantages of the stapler of this invention.

Figure 17 is a partial exploded perspective view of a particularly preferred embodiment of a portion of the apparatus of Figure 1.

Figure 18 is a sectional view taken along the line 18—18 in Figure 17 showing the parts of Figure 17 assembled.

Detailed Description of the Invention

Although the principles of the invention are applicable to other gas powered surgical stapling type instruments such as ligating and dividing instruments in which one or more staple-like elements are first advanced and then formed by the instrument, the invention will be illustratively described in its application to skin and fascia type surgical staplers. Also, although the invention is applicable to surgical staplers having other constructions, the invention will be illustratively described in its application to surgical staplers in which a staple cartridge containing a plurality of staples and including staple advancing and forming elements is mounted in a holder which includes the gas supply the pneumatic actuator, and control elements. In the particular embodiment shown and described herein the staple cartridge is permanently mounted in the holder. However, it will be understood that the cartridge could be removably mounted in the holder if desired. The staple cartridge will be assumed to be constructed as shown in U.S. patent 3,650,453 or U.S. patent 3,717,294. The construction and operation of the staple cartridge forms no part of the present invention and will be referred to herein only to the extent thought necessary to facilitate understanding of this invention.

I. Overall Construction and Operation

As shown in Figure 1, a surgical stapler 10 constructed in accordance with the principles of this invention includes holder 12 and staple cartridge 14. Staple cartridge 14 is shown out of holder 12 in Figure 1 for clarity, although it is normally mounted in socket 16 in the forward end portion or nose 18 of the barrel 24 of holder 12. As is described in greater detail below, nose 8 and portions of the mechanism inside barrel 24 are rotatable about the longitudinal axis of barrel 24 as indicated by the arrow 19 so that staple cartridge 14 can be rotated to any orientation relative to barrel 24. Holder 12 has an exterior shell or housing 20 (shown cut away to a large extent in Figure 1), which includes handle portion

22 and barrel portion 24. Handle portion 22 is shaped to fit easily into the hand as shown in Figure 2. Projecting from housing 20 in a position easily reached by the thumb of the hand holding handle 22 is a push button control 26.

In use as shown in Figure 2, staple cartridge 14 is mounted in holder 12. Handle 22 is held in the hand with the thumb over push button 26. The stapler is held so that the staple forming distal end of staple cartridge 14 is over the wound or incision 30 to be closed. Typically, this will mean that the staple cartridge is pointing downward. Handle 22 will then also be angled downwardly away from barrel 24 as is most convenient for the user. With the distal end of staple cartridge 14 close to or touching the tissue 32 to be stapled, push button 26 is momentarily depressed. In response, a staple is advanced to the distal end of staple cartridge 14 and then inserted into the tissue and formed into its final shape. In Figure 2, the stapler is positioned to provide the next staple in a row of staples 34, 36, 38 for closing skin wound 30.

The advancing and forming of a staple is better shown in Figures 13—15. At the start of a staple driving stroke as shown in Figure 13, staple driver 40 in staple cartridge 14 engages staple 42 and advances it toward staple forming anvil 44 at the distal end of the cartridge. When staple 42 reaches anvil 44 as shown in Figure 14, the pointed ends of staple 42 have entered the tissue to be stapled on respective opposite sides of wound 30. Further motion of staple driver 40 bends or forms staple 42 around anvil 44 as shown in Figure 15 so that the staple is fully formed and the tissue is pulled and held together to close wound 30.

Returning to Figure 1 and the general construction of stapler 10, inside the handle portion 22 of holder 12 is a container 50 of relatively low pressure gas. The pressure of the gas in container 50 during operation of the stapler is typically less than 200 p.s.i.g., and preferably in the range from about 30 p.s.i.g. to about 100 p.s.i.g. Any suitable non-toxic gas can be used. Suitable gases include halogenated hydrocarbons which are gaseous at room temperature, e.g., fluorinated hydrocarbons such as Freon 12 or chlorinated hydrocarbons such as Freon 152A. Container 50 dispenses the relatively low pressure gas through stem 54, actuator 52, and conduit 56 when actuator 52 is pressed down on stem 54.

Inside the rear of holder barrel 24 is a pneumatic actuator 60. Actuator 60 includes a pneumatic cylinder 62, which is closed at its rear end (out of sight in Figure 1) and open at its forward end, and a pneumatic piston 64 (not visible in Figure 1, but clearly visible in Figure 3 and subsequent figures) mounted for reciprocal motion in cylinder 62 parallel to the longitudinal axis of barrel 24. For reasons which will be more apparent hereinafter, cylinder 62 is preferably circular in transverse cross section so that piston 64 is rotatable about the longitudinal axis of cylinder 62. As shown, for example, in Figure 3, piston 64 is pneumatically sealed to cylinder 62 by gasket 66 of molded polyethylene or the like. Gas dispensed from container 50 is supplied to pneumatic actuator 60 via conduit 56 which admits the gas to cylinder 62 behind piston 64 to drive piston 64 forwardly in the cylinder.

Piston 64 is connected to staple driver 40 in staple cartridge 14 via mechanical linkage 70, only partially visible in Figure 1 but which includes components 200, 210, and 230 shown in other figures and described in detail below. As is explained in more detail below, mechanical linkage 70 matches the force available from pneumatic actuator 60 to the force required to move staple driver 40 through the various portions of its stroke to make more efficient use of the available pneumatic energy.

II. Construction and Normal Operation of the Control Mechanism

As shown, for example, in Figure 3, dispenser actuator 52 is normally held off the top of stem 54 by compression spring 100 which bears against the top of container 50 and the bottom of actuator 52. Stem 54 is therefore normally not depressed by actuator 52 and no gas flows from container 50. In addition, conduit 56 and pneumatic actuator 60 are normally vented to the atmosphere through the enlarged passageway in actuator 52 around stem 54.

Push button 26 is mounted on lever 110 which is pivoted about axis 112 and normally held outward (to the right as viewed in Figure 3) by spring 114. The end of lever 110 opposite pivotal axis 112 contacts the rear end of movable cam 120, shown in more detail in Figures 9 and 10. Cam 120 is mounted for reciprocal sliding motion along the outer side surface of cylinder 62 and is biased toward the rear by tension spring 122. Cam 120 can be moved forward by operation of push button 26, and also moves forward with piston 64 as a result of cam clip 124 which is formed around the side surface of cylinder 62 and which contacts the forward surface of piston 64 at one end and the rear surface of cam 120 at the other end.

Cam 120 operates on pivoting cam followr 130, also shown in more detail in Figures 9 and 10. Cam follower 130 pivots about axis 132. Cam follower 130 is biased against cam 120 by the force of compression spring 100 acting through actuator 52 and lever 140. When cam 120 moves forward, as described in more detail below, cam follower 130 pivots counter-clockwise about axis 132. When thus pivoted, cam follower 130 pivots lever 140 clockwise about its axis 142. Lever 140 then depresses actuator 52, causing pressurized gas to flow from container 50 through conduit 56 into cylinder 62 behind piston 64. The far end of lever 140 is connected to sliding weight 150 which is provided to improve the balance of the instrument and to slow down and quiet the return motion of lever 140 at the end of the pneumatic stroke as described in more detail below.

The trigger or control mechanism just de-

scribed normally provides a complete pneumatic stroke of the apparatus in response to only momentary operation of push button 26. Push button 26 does not have to be held down throughout the stroke. In addition, the control mechanism provides only one pneumatic stroke in response to each operation of push button 26 even though the push button may be held down longer than is required to initiate a pneumatic stroke. An operating cycle cannot begin until the preceding operating cycle has been completed. The normal sequence of operation of the control mechanism is illustrated in Figures 4—8 and will now be described in detail.

In Figure 4 push button 26 has been depressed by the operator of the instrument. This pivots lever 110 counter-clockwise about axis 112 and initiates forward motion of cam 120 and cam clip 124. As cam 120 moves forward, cam follower 130 rides down the inclined portion 162 of driving stroke cam surface 160 (see also Figures 9 and 10). Cam follower 130 is guided into driving stroke cam surface 160 by cooperation of beveled lead-in surface 134 on cam follower 130 and raised rail 164 on cam 120. As cam follower 130 rides down inclined surface 162, it pivots counter-clockwise around axis 132. This in turn pivots lever 140 clockwise about axis 142 and depresses actuator 52. As actuator 52 is depressed, it first compresses spring 100, thereby contacting the top of stem 54 and closing off the vent passageway around the stem. Further depression of actuator 52 depresses stem 54 which allows pressurized gas to flow from container 50 through conduit 56 into cylinder 62 to initiate forward motion of piston 64. Push button 26 need only be operated long enough for piston 64 to reach the position at which it cooperates with cam clip 124 to prevent cam 120 from moving backward enough to allow the system to vent.

In Figure 5 piston 64 has been driven forward far enough to contact the end of cam clip 124. At this point, cam 120 continues to move forward with piston 64, and push button 26 can be released as shown. Gas continues to flow into cylinder 62 because cam follower 130 continues to depress actuator 52 via lever 140. Accordingly, piston 64 continues to move forward, moving with it cam 120. Cam follower 130 remains pivoted counter-clockwise as it follows the flat portion of driving stroke cam surface 160.

This operation of the apparatus continues until cam follower 130 reaches the rear end of driving stroke cam surface 160 as shown in Figure 6. Thereafter, further forward motion of cam 120 allows cam follower 130 to drop off the rear end of driving stroke cam surface 160 onto return stroke cam surface 166 as shown in Figure 7 (see also Figures 9 and 10). When cam follower 130 drops onto return stroke cam surface 166, cam follower 130 allows lever 140 to pivot counter-clockwise, thereby releasing actuator 52. This releases stem 54 and stops the flow of gas from container 50. It also vents cylinder 62 through the passageway in actuator 52 around stem 54. Piston 64 therefore begins its return stroke powered by return springs 180 and 182, described below. This repositioning of cam follower 130, lever 140, and actuator 52 at the end of the driving stroke is slowed somewhat by the effect of mass 150 on the motion of lever 140. This tends to quiet the mechanism during what would otherwise be fairly abrupt movements of several parts.

During the return stroke of the apparatus, as shown in Figure 8, cam 120 travels backward with piston 64 under the influence of tension spring 122. Cam follower 130 bypasses driving stroke cam surface 160 and follows return stroke cam surface 166 as a result of cooperation of lead-in surfaces 136 and 168 on cam follower 130 and cam 120, respectively, at the start of the return stroke (see also Figures 9 and 10). At the end of the return stroke, cylinder 62 has been completely vented and all parts of the apparatus are back in their initial positions shown in Figure 3. The apparatus is accordingly ready to begin another operating cycle in response to another operation of push button 26.

If push button 26 is held down longer than necessary to initiate the driving stroke of the apparatus, the stapler performs normally except that cam 120 does not complete its return motion until push button 26 is released. This is because the end of lever 110 adjacent the rear of cam 120 stops the return motion of cam 120 before that motion is complete. When push button 26 is subsequently released, the return motion of cam 120 resumes and cam 120 returns to its initial position shown in Figure 3. Until cam 20 has returned to its initial position, the stapler can not begin another operating cycle. Accordingly, the stapler performs only one operating cycle in response to each operation of push button 26, regardless of how long the push button is held down beyond the time required to initiate an operating cycle as described above. Once an operating cycle has been initiated, the stapler is prevented from beginning another operating cycle until push button 26 has been released and the first operating cycle is complete.

III. Construction and Operation of the Abort Mechanism

An additional feature of the control mechanism enables the user to interrupt a staple driving stroke after such a stroke has begun. This is accomplished by a second operation of push button 26 at any time during a driving stroke of piston 64. For this purpose (see, for example, Figures 3 and 11), finger 170 is mounted on lever 110 so that it extends to a point on the side of cam follower 130 opposite rail 164 on cam 120 when cam follower 130 is on driving stroke cam surface 160. Near the end of finger 170, cam follower 130 includes a protrusion 138 positioned so that the end of finger 170 misses the protrusion when push button 26 is first operated to initiate a staple driving stroke, but also positioned so that the end of finger 170 hits the protrusion if push button 26 is operated again while cam follower 130 is

pivoted counter-clockwise, i.e., while cam follower 130 is on driving stroke cam surface 160. The relative positions of protrusion 138 and the end of finger 170 while cam follower 130 is on driving stroke cam surface 160 are shown in Figures 5 and 6, and especially in Figure 11, which (together with Figure 12) is intended particularly to illustrate this feature of the invention.

Protrusion 138 and finger 170 are designed so that finger 170 will pass over protrusion 138 without disturbing cam follower 130 when push button 26 is released after a staple driving stroke has been initiated. If, however, push button 26 is operated again during the staple driving stroke, the end of finger 170 firmly contacts protrusion 138, thereby forcing cam follower 130 to jump over rail 164 as shown in Figure 12 from driving stroke cam surface 160 to return stroke cam surface 166. This immediately stops the staple driving stroke by releasing actuator 52 and venting cylinder 62. With cam follower 130 on return stroke cam surface 166, the apparatus performs as much of a return stroke as is required to return the apparatus to its initial condition. In most instances, the apparatus is not harmed by thus aborting a staple driving stroke and it can be used again simply by re-depressing push button 26.

IV. Construction and Operation of the Staple Driving Mechanism

Details of the staple driving mechanism are best seen in Figures 13—15, which also illustrate the operating sequence of this mechanism. As shown in Figure 13, for example, the staple driving mechanism includes a yoke 200 mounted on the forward surface of piston 64. At its forward open end, yoke 200 has two symmetrical cam surfaces respectively designated by the general reference numbers 202 and 204. Each of these cam surfaces includes a first portion 206 at the end of the yoke. Cam surface portions 206 are preferably substantially perpendicular to the central axis of cylinder 62. Adjacent to portions 206, each yoke cam surface includes a second portion 208 in the cleft of yoke 200. Cam surface portions 208 are synclinal (i.e., inclined toward one another in the direction of the rear of yoke 200), and each portion 208 preferably forms an obtuse angle with the adjacent portion 206.

Mounted forwardly of cylinder 62 is a four bar linkage designated generally by the reference number 210. Four bar linkage 210 includes bars 212, 214, 216, and 218 which are joined at their adjacent ends by hinge or pin connections 222, 224, 226, and 228 (e.g., the adjacent ends of bars 212 and 214 are joined by hinge or pin connection 222; and adjacent ends of bars 214 and 216 are joined by hinge or pin connection 224; and so on around linkage 210). Bars 212 and 214 are both of the same length, and bars 216 and 218 are also both of the same length, which may be the same as or somewhat different from the length of bars 212 and 214. The location of rearmost pin 222 is fixed longitudinally relative to cylinder 62 (see also Figure 3), preferably in line with the central axis of cylinder 62 and yoke 200. The remaining pins 224, 226, and 228 are free to move longitudinally relative to cylinder 62.

Attached to pin 226 is a push rod 230 (see, also, Figure 3). Push rod 230 is slidably mounted relative to cylinder 62 so that it can reciprocate parallel to the axis of cylinder 62. As best seen in Figure 3, main return spring 180 is a compression spring mounted between the rear end of push rod 230 and a forward portion of the cage 250 described below. Secondary return spring 182 is another compression spring mounted between the rear end of push rod 230 and the forward surface of piston 64. The forward end of push rod 230 includes a tongue 232 engaged with a mating recess or aperture near the rear end of staple driver 40 in staple cartridge 14.

Four bar linkage 210, push rod 230, and return spring 180 are all mounted in a generally cylindrical cage 250 best seen in Figures 1 and 3. Cage 250 is rotatably mounted in barrel 24 concentric with the longitudinal axis of cylinder 62. Nose portion 18 of barrel 24 is fixed on the forward end of cage 250. Cage 250 is retained in barrel 24 by cooperation of outwardly extending lips 252 on cage 250 and inwardly extending portions 28 on barrel 24. Pin 222 is fixed longitudinally by being mounted in a rear portion of cage 250. The rear portion of cage 250 also includes two longitudinally extending slots 254 through which the portions of four bar linkage 210 adjacent pins 224 and 228 extend outward, at least when the stapler is in its initial condition (see Figure 13). The forward portions of yoke 200 extend longitudinally into slots 254 behind four bar linkage 210 to contact that linkage as described in detail below. Accordingly, cage 250 and therefore push rod 230, four bar linkage 210, yoke 200, and piston 64 all rotate with staple cartridge 14 and nose 18. Cylinder 62 and the control mechanism do not rotate. The stapler can thus be operated with staple cartridge 14 at any rotational orientation relative to the remainder of the apparatus.

In the initial condition of the staple driving mechanism shown in Figure 13 (i.e., prior to the application of pneumatic pressure to piston 64), return spring 180 holds push rod 230 in its rearmost position (see also Figure 3). Push rod 230, acting through pin 226, pushes the portions of four bar linkage 210 adjacent pins 224 and 228 to the rear. These portions of the four bar linkage respectively push on the end portions 206 of yoke cam surfaces 202, 204, thereby pushing piston 64 to the rear. Return spring 182, which has a much lower spring constant than return spring 180 and which never exerts sufficient force to separate yoke 200 from four bar linkage 210, also pushes back on piston 64.

When pressurized gas is admitted to cylinder 62, piston 64 moves forward and the staple driving stroke begins. During the staple driving stroke, the forward motion of piston 64 imparts forward motion to staple driver 40 via the mechanical linkage including yoke 200, four bar linkage 210, and push rod 230. This mechanical

linkage has essentially two modes of operation with significantly different mechanical advantage characteristics.

During the first portion of the staple driving stroke when the staple is being advanced from the initial position shown in Figure 13 to the staple forming position shown in Figure 14, the end portions 206 of yoke cam surfaces 202 and 204 push on the portions of four bar linkage 210 adjacent pins 224 and 228 in a direction substantially parallel to the direction of motion of piston 64. Accordingly, during this portion of the staple driving stroke four bar linkage 210 amplifies the forward motion of piston 64, so that for each increment of motion of piston 64, push rod 230 moves forward a substantially larger increment. As a concomitant of this amplification of motion, four bar linkage 210 substantially reduces the force applied to push rod 230 as compared to the force exerted by piston 64. The output force of four bar linkage 210 is, however, sufficient to overcome the return spring force and supply the relatively small force required to advance staple 42 to the staple forming position adjacent anvil 44.

As staple 42 reaches anvil 44, the mechanical linkage shifts to its second mode of operation in which the force exerted by piston 64 is substantially amplified to produce the substantially larger force required to form the staple by bending it around anvil 44. This mode of operation continues from the time the staple first reaches the staple forming position as shown in Figurre 14 to the end of the staple driving stroke when the staple is fully formed as shown in Figure 15. During this mode of operation the inclined portions 208 of yoke cam surfaces 202 and 204 act on the portions of four bar linkage 210 adjacent pins 224 and 228. Accordingly, as piston 64 and yoke 200 advance, inclined yoke cam surfaces 208 act as wedges to push inward on four bar linkage pin connections 224 and 228. This wedge-like action of yoke 200 on four bar linkage 210 substantially amplifies the force of piston 64 as applied to push rod 230. Accordingly, sufficient force is applied to push rod 230 to supply the relatively large force required to form staple 42 around anvil 44, as well as to continue to overcome the return spring force. This amplification of force is accompanied by a reduction in motion. Thus during this portion of the staple driving stroke, each increment of motion of piston 64 produces a substantially smaller increment of motion of push rod 230 and staple driver 40. It should also be noted that during this second portion of the staple driving stroke secondary return spring 182 is gradually compressed.

After completion of the staple driving stroke when cylinder 62 begins to be vented, secondary return spring 182 pushes piston 64 back to initiate the spring powered return stroke of the apparatus. The initial backward thrust on piston 64 provided by return spring 182 relieves the wedging or pinching effect of cam surfaces 208 on four bar linkage 210. This facilitates movement of the portions of four bar linkage 210 adjacent pins 224 and 228 out of yoke 200 as is necessary to allow the staple driving mechanism to return to its initial condition shown in Figure 13 at the end of the return stroke. Staple driver 40 is then positioned behind another staple 42 ready to begin another cycle of operation.

The differential mechanical advantage provided by the mechanical linkage including yoke 200 and four bar linkage 210 is important to the economical design of the stapler, including its ability to provide the relatively large forces required to form a staple with a relatively small pneumatic actuator 60 supplied with relatively low pressure gas, as well as its efficient use of the gas in its gas supply. These features of the stapler are further illustrated in Figure 16.

The force required to advance and then form a staple is typically represented as a function of staple driver displacement by the curve labelled "force required" in Figure 16. As shown by this curve, the force required to advance the staple to the staple forming position (the portion of the staple driving stroke labelled "advance staple" in Figure 16) is relatively low. The force required to form the staple, however, is relatively high. This is the portion of the staple driving stroke labelled "form staple" in Figure 16.

The force available from the mechanical linkage in the stapler of this invention is typically represented by the curve labelled "force available" in Figure 16. This force closely matches the force required to advance and then form the staple during the various portions of the staple driving stroke. In particular, throughout the staple driving stroke the force available is always at least equal to but not substantially greater than the force required. This variable available force is produced by the mechanical linkage from a substantially constant force exerted by piston 64 throughout its driving stroke. This mechanical linkage has a first relatively low and preferably substantially constant value of mechanical advantage during the first or staple advancing portion of the stroke, and a second relatively high and again preferably substantially constant value of mechanical advantage during the second or staple forming portion of the stroke. The constant force exerted by the piston is typically greater than the relatively low force required or available during the staple advancing portion of the stroke, but less than the relatively high force required or available during the staple forming portion of the stroke. Preferably, the pneumatic energy expended during each incremental advance of piston 64 (given by the expression PdV, where P is the pressure of the gas supplied by gas supply 50 and dV is the corresponding incremental change in the volume enclosed by cylinder 62 and piston 64) is approximately equal to the mechanical work performed during the corresponding incremental advance of staple driver 40 (given by the expression Fdx, where F is the force required to advance staple driver 40 and dx is the corresponding incremental advance of the staple driver). Accordingly, sub-

stantially all of the pneumatic energy expended in each stroke is converted to required mechanical work, and the available pneumatic energy is used very efficiently.

By way of contrast, if a direct pneumatic drive were used to advance staple driver 40, the pneumatic actuator would have to be sized to provide the maximum required force throughout its entire stroke in order to meet that maximum force requirement. If low pressure gas were used, this would necessitate a pneumatic actuator of much larger diameter than is required in the stapler of this invention. In addition, the curve of force available for such a stapler would be represented by the broken line in Figure 16, and an amount of pneumatic energy proportional to the area between this line and the curve labelled "force available" would be wasted (as compared to the stapler of this invention) during each staple driving stroke. Similarly, if an indirect drive with a constant value of mechanical advantage were used to make possible the use of a smaller diameter pneumatic actuator, the pneumatic actuator would have to be made much longer than the present actuator and the same amount of pneumatic energy would be wasted during each staple driving stroke.

Thus the stapler of this invention is capable of producing the relatively large forces required to form one or more staples with a relatively small pneumatic actuator supplied with relatively low pressure gas, while at the same time making efficient use of the gas supply. Although the following parameters may vary for different types of instruments and are specified here for purposes of illustration only, the gas pressure is typically as mentioned above, the piston area is typically less than 2 square inches (preferably in the range from .5 to 1 square inch), and the stroke of the piston is typically less than 2 times the displacement of the staple (preferably in the range from 1 to 2 times the staple displacement).

V. Other Features

As will be apparent from the foregoing, the stapler of this invention can be readily manufactured as a relatively low cost disposable item because of the use of relatively low pressure gas. Thus container 50 and cylinder 62 can be of relatively thin lightweight metal such as aluminum. Most of the remaining parts (with the obvious exception of the springs and the possible exception of a few relatively high stress elements such as push rod 230 which may be metal) can be made of plastic. As a disposable item, the stapler is preferably sold in a sterile condition in packaging designed to keep it sterile until it is used. The stapler is used in a single surgical procedure and then discarded. The user thereby avoids all labor and expense associated with cleaning and sterilizing the instrument.

In a preferred embodiment, gas container 50 is provided with over-pressure relief means for automatically releasing the pneumatic fluid from container 50 in the event that the pressure of the pneumatic fluid exceeds a predetermined threshold level. This threshold level is chosen to be below the pressure at which container 50 would burst or explode. The instrument is thereby made safer, especially when disposed of using high temperatures (e.g., by incineration). Although any of a wide variety of over-pressure relief means such as pressure relief valves can be used, a particularly preferred pressure relief means is illustrated in Figures 17 and 18 and described in detail below.

As shown in Figures 17 and 18, container 50 is made with a bottom wall portion 280 which is curved inwardly (i.e., concave) in the center. The periphery of container bottom 280 rests on a peripheral portion of disk 290. Disk 290 is held in place by insert 300 which fits into the butt of handle 22 (see also Figure 1). Disk 290 is made of a material which is substantially harder and stronger than container bottom 280. For example, if container bottom 280 is aluminum, disk 290 may be iron or steel.

A central portion 292 of disk 290 is partly punched out and bent substantially perpendicular to the plane of disk 290 so that it points toward the concave portion of container bottom 280. The end of punched out portion 292 is sharply pointed. Portion 292 is accordingly referred to for convenience herein as piercer 292.

The end of piercer 292 normally does not touch concave container bottom 280. However, if the pressure in container 50 becomes excessively high, container 50 is designed so that the higher than normal gas pressure in the container causes container bottom 280 to deform outward (i.e., to flatten out or become convex) before container 50 explodes. Container bottom 280 is thus forced into contact with piercer 292, and because piercer 292 is relatively sharp and both stronger and harder than container bottom 280, piercer 292 pierces container bottom 280, thereby allowing the gas in container 50 to escape harmlessly.

Many other arrangements of piercing element 292 are possible. For example, piercing element 292 could be a separate element mounted on disk 290 by welding, soldering, or the like. Piercing element 292 could alternatively be mounted on a structure such as a strap, harness, or cage attached to the sides of container 50.

Although the stapler of this invention is preferably completely disposable, the holder could alternatively be made as a permanent instrument having a replaceable gas supply and accepting disposable staple cartridges.

It will be understood that the foregoing is merely illustrative of the principles of this invention, and that various modifications can be made by those skilled in the art without departing from the scope and spirit of the invention. For example, the stapler need not have the particular overall configuration shown and described herein, but may have any other shape convenient for the user in any intended application. Also, although the stapler shown and described herein is intended for stapling skin and fascia, the stapler

could be disigned for other surgical procedures such as ligating and dividing.

Claims

1. A gas powered surgical stapling apparatus including a pneumatic piston (64) and a staple driver (40) for advancing a staple (42) to a staple forming position and then forming the staple, a relatively low force being required to advance the staple to the staple forming position and a relatively high force being required to form the staple, characterized in that the apparatus comprises a mechanical linkage (70) between the pneumatic piston (64) and the staple driver (40) for producing from a substantially constant force provided by the pneumatic piston (64) throughout its driving stroke the relatively low force required during the advance of the staple (42) to the staple forming position and the relatively high force required during forming of the staple (42), the mechanical linkage (70) comprising a four bar linkage (210) disposed in a plane parallel to the translational axis of the staple driver and having a first hinge connection (226) attached to the staple driver (40), an opposite second hinge connection (222) fixed at a point on an axis through the first hinge connection parallel to the translational axis of the staple driver, and third and fourth hinge connections (224, 228) repectively spaced on opposite sides of the axis through the first and second hinge connections (226, 222); and cam means (200) connected to the pneumatic piston and having first and second cam surfaces (202, 204) for respectively operating on the third and fourth hinge connections (224, 228) to push the third and fourth hinge connections (224, 228) substantially parallel to the translational axis of the staple driver (40) during a first portion of the driving stroke of the pneumatic piston (64) corresponding to the advance of the staple (42) and to push the third and fourth hinge connections (224, 228) toward one another during the remainder of the driving stroke of the pneumatic piston (64) corresponding to forming the staple (42).

2. The apparatus defined in claim 1, characterized in that the work performed by the pneumatic pressure applied to the pneumatic piston (64) during each increment of motion of the piston (64) is at least equal to but not substantially greater than the work required to cause the associated incremental advance of incremental forming of the staple (42).

3. The apparatus defined in claim 1, characterised in that the mechanical advantage of the mechanical linkage (70) changes from a first value to a second substantially different value when advance of the staple (42) is substantially complete and forming of the staple (42) is about to begin.

4. The apparatus defined in claim 1, characterized in that the mechanical advantage of the mechanical linkage (70) has a first substantially constant value during advance of the staple (42) and a second substantially different but substantially constant value during forming of the staple (42).

5. The apparatus defined in claim 1, characterized in that the staple driver (40) translates to advance and form the staple (42).

6. The apparatus defined in claim 1, characterized in that each of the first and second cam surfaces (202, 204) comprise a first portion (206) substantially perpendicular to the translational axis of the staple driver for operating on the associated hinge connection during the first portion of the driving stroke of the pneumatic piston and an adjacent second portion (208) which is inclined relative to the translational axis of the staple driver (40) for operating on the associated hinge connection during the second portion of the stroke of the pneumatic piston (64).

7. The apparatus defined in claim 6, characterized in that the second portion (208) of each cam surface (202, 204) forms an obtuse angle with the adjacent first portion (206).

8. The apparatus defined in claim 1, characterized in that it further comprises:

a manually operable control (26);

means (110, 120, 130) responsive to momentary operation of the manually operable control (26) for normally causing the pneumatic piston (64) to perform one complete cycle of operation including a driving stroke followed by a return stroke which returns the piston (64) to its initial condition; and

means (120) responsive to operation of the manually operable control (26) during the driving stroke of the pneumatic piston (64) for interrupting the driving stroke and causing the piston (64) to return to its initial condition.

9. The apparatus defined in claim 8, characterized in that the means responsive to momentary operation of the manually operable control includes means (110) for preventing another cycle of operation from beginning until the manually operable control has been released and the preceding cycle of operation has been completed.

10. The apparatus defined in claim 8, characterized in that the means responsive to momentary operation of the manually operable control comprises:

a movable cam member (120) mounted so that it normally travels with the pneumatic piston (64) and having a driving stroke cam surface (160) and a return stroke cam surface (166);

a cam follower (130) for normally engaging the driving stroke cam surface (160) during a driving stroke of the pneumatic piston (64) and the return stroke cam surface (66) during a return stroke of the piston (64) and for causing pneumatic pressure to be applied to the pneumatic piston (64) only while engaged with the driving stroke cam surface (160); and

means (110) for initiating motion of the movable cam member (120) so that the cam follower (130) engages the driving stroke cam surface (160) in response to operation of the manually operable control (26).

11. The apparatus defined in claim 10,

characterized in that the means responsive to momentary operation of the manually operable control further comprises:

means for preventing the movable cam member (120) from returning to its initial position during the return stroke of the pneumatic piston (64) if the manually operable control is still being operated, thereby preventing initiation of another cycle of operation until the manually operable control (26) has been released and the preceding cycle of operation has been completed.

12. The apparatus defined in claim 11, characterized in that it further comprises:

means responsive to operation of the manually operable control during the driving stroke of the pneumatic piston (64) for causing the cam follower (130) to leave the driving stroke cam surface (160) and engage the return stroke cam surface (166) to interrupt the driving stroke and cause the piston (64) to return to its initial condition.

13. The apparatus defined in claim 11, characterized in that the cam follower (130) causes pneumatic pressure to be vented from the pneumatic piston (64) when not engaged with the driving stroke cam surface (160) and wherein the return stroke of the pneumatic piston is powered by return spring means (180).

14. The apparatus defined in claim 1, characterized in that the work performed by the pneumatic piston (64) during the course of its driving stroke is approximately equal to the work required to advance and form the staple (42).

15. The apparatus defined in claim 1, characterized in that the mechanical linkage (70) amplifies the motion of the pneumatic piston (64) during the first part of its driving stroke corresponding to advance of the staple and amplifies the force of the pneumatic piston (64) during the remainder of its driving stroke corresponding to forming of the staple (42).

16. The apparatus defined in claim 5, characterized in that the cam surfaces (200) comprise a yoke connected to the pneumatic piston (64) and opening toward the four bar linkage (210), the yoke having first and second end surfaces (206) substantially perpendicular to the axis of the pneumatic piston for respectively operating on the third and fourth hinge connections (224, 228) during the first portion of the driving stroke of the pneumatic piston (64) and third and fourth synclinal surfaces (208) respectively adjacent the first and second end surfaces (206) for respectively operating on the third and fourth hinge connections (224, 228) during the remainder of the driving stroke of the pneumatic piston (64).

17. The apparatus defined in any one of claims 1—16, characterized in that it is a self-contained gas powered holder (12) for holding and actuating a cartridge (14) containing surgical staples (42), the holder comprising:

a source of pressurized pneumatic fluid (50);

a pneumatic cyclinder (62) pneumatically connected to the source of pressurized pneumatic fluid (50);

a pneumatic piston (64) mounted for reciprocal motion in the cylinder (62); and

the mechanical linkage (70) between the pneumatic piston (64) and the actuatable part of the cartridge.

18. The apparatus defined in any one of claims 1—16, characterized in that it is a self-contained gas powered surgical stapler comprising:

a source of pressurized (50) in the stapler;

a pneumatic actuator including a cylinder (62) and a piston reciprocally mounted in the cylinder (62);

gas conduit means (56) including valve means for selectively conducting pressurized gas from the source of gas (50) to the pneumatic actuator to drive the piston (64) in a driving stroke;

a staple driver (40) for advancing and forming the staple (42); and

the mechanical linkage (70) between the piston (64) and the staple driver (40).

19. The apparatus defined in claim 18, characterized in that the staple driver (40) is rotatable relative to at least a portion of the pneumatic actuator.

20. The apparatus defined in claim 19, characterized in that the pneumatic actuator piston is a circular cylinder (62), wherein the piston (64) is rotatable about its longitudinal axis relative to the pneumatic actuator cylinder, and wherein the mechanical linkage (70) and the staple driver (40) rotate with the piston (64).

21. The apparatus defined in claim 18, characterized in that the source (50) of pressurized gas supplies gas having pressure less than 200 p.s.i.g.

22. The apparatus defined in claim 18, characterized in that the source of pressurized gas (50) includes over-pressure relief means for automatically releasing the pressurized gas from the pressurized gas source when the pressure of the gas in the pressurized gas source exceeds a predetermined threshold value below the pressure at which the pressurized gas source would burst.

23. The apparatus defined in claim 22, characterized in that the source of pressurized gas is a container (50) having a wall portion (280) which is normally concave inward and which deforms outwardly when the pressure of the gas in the container exceeds the predetermined theshold value, and the apparatus further comprises piercer means (290, 292) disposed adjacent the normally concave inward container wall portion (280) for piercing the container wall portion and releasing the gas when the wall portion deforms outwardly.

Revendications

1. Agrafeuse chirurgicale actionnée par un gaz comprenant un piston pneumatique (64) et un organe (40) d'entraînement des agrafes pour faire avancer une agrafe (42) jusqu'à la position de mise en forme des agrafes puis mettre en forme l'agrafe, une force relativement faible étant re-

quise pour faire avancer l'agrafe jusqu'à la position de mise en forme de agrafes et une force relativement élevée étant requise pour mettre en forme l'agrafe, caractérisée en ce que l'agrafeuse comprend une tringlerie mécanique (70) disposée entre le piston pneumatique (64) et l'organe (40) d'entraînement des agrafes pour produire, à partir d'une force sensiblement constante produite par le piston pneumatique (64) sur toute sa course d'entraînement, la force relativement petite requise pendant l'avance de l'agrafe (42) jusqu'à la position de mise en forme des agrafes, et la force relativement élevée requise pendant la mise en forme de l'agrafe (40), la tringlerie mécanique (70) comprenant un parallélogramme articulé (210) disposé dans un plan parallèle à l'axe de translation de l'organe d'entraînement des agrafes, et ayant une première articulation (226) fixée à l'organe (40) d'entraînement des agrafes, une seconde articulation (222) opposée fixée en un point qui est situé sur un axe qui passe par la première articulation et est parallèle à l'axe de translation de l'organe d'entraînement des agrafes, et des troisième et quatrième articulations (224, 228) respectivement espacées sur les côtés opposés de l'axe passant par les première et seconde articulations (226, 228), et des moyens (200) formant came reliés au piston pneumatique et ayant des première et seconde surfaces de came (202, 204) pour agir respectivement sur les troisième et quatrième articulations (224, 228), afin de pousser le troisième et quatrième articulations (224, 228) sensiblement parallèlement à l'axe de translation de l'organe de l'entraînement des agrafes pendant une première partie de la course d'entraînement du piston pneumatique (64) correspondant à l'avance de l'agrafe (42), et de pousser les troisième et quatrième articulations (224, 228) l'une vers l'autre pendant le reste de la course d'entraînement du piston pneumatique (64) qui correspond à la mise en forme de l'agrafe (42).

2. Agrafeuse selon la revendication 1, caractérisée en ce que le travail effectué par la pression pneumatique appliquée au piston pneumatique (64) pendant chaque incrément de mouvement du piston (64) est au moins égal au travail requis pour provoquer l'avance incrémentielle associée ou la mise en forme incrémentielle associée de l'agrafe (42) mais n'est pas sensiblement supérieur à ce travail.

3. Agrafeuse selon la revendication 1, caractérisée en ce que l'effet mécanique de la tringlerie mécanique (70) passe d'une première valeur à une seconde valeur sensiblement différente lorsque l'avance de l'agrafe (42) est sensiblement achevée et que la mise en forme de l'agrafe (42) est sur le point de commencer.

4. Agrafeuse selon la revendication 1, caractérisée en ce que le développement de la tringlerie mécanique (70) a une première valeur sensiblement constante pendant l'avance de l'agrafe (72) et une seconde valeur nettement différente de la première mais sensiblement constante pendant la mise en forme de l'agrafe (42).

5. Agrafeuse selon la revendication 1, caractérisée en ce que l'organe (40) d'entraînement des agrafes se déplace en translation pour faire avancer et mettre en forme l'agrafe (42).

6. Agrafeuse selon la revendication 1, caractérisée en ce que chacune des première et seconde surfaces de came (202, 204) comprend une première partie (206) sensiblement perpendiculaire à l'axe de translation de l'organe d'entraînement des agrafes pour agir sur l'articulation associée pendant la première partie de la course d'entraînement du piston pneumatique, et une seconde partie adjacente (208) qui est inclinée par rapport à l'axe de translation de l'organe (40) d'entraînement des agrafes pour agir sur l'articulation associée pendant la seconde partie de la course du piston pneumatique (64).

7. Agrafeuse selon la revendication 6, caractérisée en ce que la seconde partie (208) de chaque surface de came (202, 204) fait un angle obtus avec la première partie adjacente (206).

8. Agrafeuse selon revendication 1, caractérisée en ce qu'elle comporte, en outre:

une commande (26) actionnable manuellement;

des moyens (110, 120, 130) fonctionnant en réponse à un actionnement momentané de la commande actionnable manuellement, pour provoquer normalement l'exécution par le piston pneumatique (64) d'un cycle de fonctionnement complet comprenant un course d'entraînement suivie d'une course de retour qui ramène le piston (64) à sa condition initiale; et

des moyens (120) fonctionnant en réponse à l'actionnement de la commande (26) actionnable emanuellement pendant la course d'entraînement du piston pneumatique (64), pour interrompre la course d'entraînement et pour provoquer le retour du piston (64) à sa condition initiale.

9. Agrafeuse selon la revendication 8, caractérisée en ce que les moyens fonctionnant en réponse à l'actionnement momentané de la commande actionnable manuellement comprennent des moyens (110) pour empêcher un autre cycle de fonctionnement de commencer, tant que la commande actionnable manuellement n'a pas été relâchée et que le cycle de fonctionnement précédent n'a pas été achevé.

10. Agrafeuse selon la revendication 8, caractérisée en ce que les moyens fonctionnant en réponse à l'actionnement momentané de la commande actionnée manuellement comprennent:

un organe de came mobile (120) monté de façon à se déplacer normalement avec le piston pneumatique (64) et ayant une surface de came (160) de course d'entraînement et une surface de came (166) de course de retour;

un organe (130) suiveur de came conçu de manière à être normalement en appui contre la surface de came (160) de course d'entraînement pendant une course d'entraînement du piston pneumatique (64), et contre la surface de came (166) de course de retour pendant une course de retour du piston (64), de manière à ne porvoquer l'application d'une pression pneumatique au pis-

ton pneumatique (64) que lorsqu'il est en appui contre la surface de came (160) de course d'entraînement; et

des moyens (110) pour déclencher le mouvement de l'organe de came mobile (180) de façon que l'organe (130) suiveur de came vienne en appui contre la surface de came (160) de course d'entrainement en réponse à l'actionnement de la commande (26) actionnable manuellement.

11. Agrafeuse selon la revendication 10, caractérisée en ce que les moyens fonctionnant en réponse à l'actionnement momentané de la commande actionnable manuellement comprennent, en outre:

des moyens pour empêcher l'organe de came mobile (120) de retourner à sa postion initiale pendant la course de retour du piston pneumatique (64) si la commande actionnable manuellement est encore en fonctionnement, empêchant, de ce fait, le déclenchement d'un autre cycle de fonctionnement, tant que la commande (26) actionnable manuellement n'a pas été relâchée et tant que la cycle de fonctionnement précédent n'a pas été achevé.

12. Agrafeuse selon la revendication 11, caractérisée en ce qu'il comporte, en outre:

des moyens fonctionnant en réponse à l'actionnement de la commande actionnable manuellement pendant la course d'entraînement du piston pneumatique (64), pour provoquer l'abandon par l'organe (130) suiveur de came de la surface de came (160) de course d'entraînement, et sa venue en appui contre la surface de came (166) de course de retour, pour interrompre la course d'entraînement et provoquer le retour du piston (64) à sa condition initiale.

13. Agrafeuse selon la revendication 11, caractérisée en ce que l'organe (130) suiveur de came provoque l'évacuation de la pression pneumatique appliquée au piston pneumatique (64) lorsqu'il n'est pas en appui contre la surface de came (160) de course d'entraînement et dans lequel la course de retour du piston pneumatique est commandée par des moyens à ressort de rappel (180).

14. Agrafeuse selon la revendication 1, caractérisée en ce que le travail effectué par le piston pneumatique (64) pendant sa course d'entraînement est approximativement égal au travail requis pour faire avancer l'agrafe (42) et la mettre en forme.

15. Agrafeuse selon la revendication 1, caractérisée en ce que la tringlerie mécanique (70) amplifie le mouvement du piston pneumatique (64) pendant la première partie de sa course d'entraînement qui correspond à l'avance de l'agrafe et elle amplifie la force du piston pneumatique (64) pendant le reste de sa course d'entraînement qui correspond à la mise en forme de l'agrafe (42).

16. Agrafeuse selon la revendication 5, caractérisée en ce que les surfaces de came (200) sont constituées par un étrier relié au piston pneumatique (64) et dont l'ouverture est orientée vers le parallélogramme articulé (210), l'étrier ayant des première et seconde surfaces d'extrémité (206) sensiblement perpendiculaires à l'axe du piston pneumatique pour agir respectivement sur les troisième et quatrième articulations (224, 228) pendant la première partie de la course d'entraînement du piston pneumatique (64), et des troisième et quatrième surfaces cynclinales (208) respectivement adjacentes aux première et seconde surfaces d'extrémité (206) pour agir respectivement sur les troisième et quatrième articulations (224, 228) pendant le reste de la course d'entraînement du piston pneumatique (64).

17. Agrafeuse selon l'une quelconque des revendications 1 à 6, caractérisée en ce qu'elle constitue un dispositif support autonome (12) actionné par un gaz pour porter et actionner une cartouche (14) contenant des agrafes chirurgicales (42), le dispositif support comprenant:

une source de fluide pneumatique sous pression (50);

un cylindre pneumatique (62) relié pneumatiquement à la source de fluide pneumatique sous pression (50);

un piston pneumatique (64) monté de façon à pouvoir se déplacer en va-et-vient dans le cylindre (62); et

la tringlerie mécanique (70) disposée entre le piston pneumatique (64) et la partie actionnable de la cartouche.

18. Agrafeuse selon l'une quelconque des revendications 1 à 16, caractérisée en ce qu'elle constitue une agrafeuse chirurgicale autonome actionnée par un gaz comprenant:

une source de gaz sous pression (50) contenue dans l'agrafeuse;

un actionneur pneumatique comprenant un cylindre (62) et un piston (64) monté mobile en va-et-vient dans le cylindre (64);

des moyens (66) de conduit de gaz comprenant des moyens de robinetterie pour conduire sélectivement la gaz sous pression depuis la source de gaz (50) jusqu'à l'actionneur pneumatique afin d'entraîner le piston (64) dans une course d'entraînement;

un organe (40) d'entraînement des agrafes pour faire avancer l'agrafe (42) et la mettre en forme; et

la tringlerie mécanique (70) disposée entre le piston (64) et l'organe (40) d'entraînement des agrafes.

19. Agrafeuse selon la revendication 18, caractérisée en ce que l'organe (40) d'entraînement des agrafes est monté rotatif par rapport au moins à une partie de l'actionneur pneumatique.

20. Agrafeuse selon la revendication 19, caractérisée en ce que le cylindre de l'actionneur pneumatique est un cylindre circulaire (62), dans lequel le piston (64) est monté rotatif autour de son axe longitudinal par rapport au cylindre de l'actionneur pneumatique, et dans lequel la tringlerie mécanique (70) et l'organe (40) d'entraînement des agrafes tournent avec le piston (64).

21. Agrafeuse selon la revendication 18, caractérisée en ce que la source (50) de gaz sous pression fournit un gaz ayant une pression mano-

métrique inférieur à 200 livres par pouce carré (soit 13, 79 bars).

22. Agrafeuse selon la revendication 18, caractérisée en ce que la source de gaz sous pression (50) comprend des moyens détendeurs de pression pour évacuer automatiquement le gaz sous pression de la source de gaz sous pression, lorsque la pression du gaz contenu dans la source de gaz sous pression dépasse une valeur de seuil prédéterminée, inférieure à la pression à laquelle la source de gaz sous pression éclaterait.

23. Agrafeuse selon la revendication 22, caractérisée en ce que la source de gaz sous pression est un réservoir (50) ayant une partie de paroi (280) qui est normalement concave vers l'intérieur et qui se déforme vers l'extérieur lorsque la pression du gaz contenu dans le récipient dépasse la valeur de seuil prédéterminée et en ce que l'agrafeuse comporte, en outre, des moyens de perçage (290, 292) disposés au voisinage de la partie de paroi (280) normalement concave vers l'intérieur du récipient, pour percer la partie de paroi du récipient et libérer le gaz lorsque la partie de paroi se déforme vers l'extérieur.

Patentansprüche

1. Druckgasbetriebene chirurgische Heftvorrichtung mit einem Preßgaskolben (64) und einem Klammernvorschub (40), um eine Klammer (42) in eine Klammersetztellung vorzuschieben und dann die klammer zu setzen, wobei eine relativ geringe Kraft erforderlich ist, um die Klammer in die Klammersetzstellung vorzuschieben, und eine relativ große Kraft erforderlich ist, um die Klammer zu setzen, dadurch gekennzeichnet, daß die Vorrichtung ein mechanisches Gelenkgetriebe (70) zwischen dem Druckgaskolben (64) und dem Klammernvorschub (40) enthält, um aus einer im wesentlichen konstanten Kraft, die der Druckgaskolben (64) während seines Arbeitshubs liefert, die relativ niedrige Kraft zu erzeugen, die während des Vorschubs der Klammer (42) in die Klammersetzstellung erforderlich ist, sowie die relativ große Kraft zu erzeugen, die während des Setzens der Klammer (42) erforderlich ist, wobei das mechanische Gelenkgetriebe (70) ein viergliedriges Gelenkgetriebe (210) enthält, das in einer Ebene parallel zur Translationsachse des Klammernvorschubs angeordnet ist und eine erste Gelenkverbindung (226) besitzt, die am Klammernvorschub (40) angebracht ist, eine gegenüberliegende zweite Glenkverbindung (222) besitzt, die an einer Stelle auf einer Achse durch die erste Gelenkverbindung parallel zur Translationsachse des Klammernvorschubs befestigt ist, sowie eine dritte und vierte Gelenkverbindung (224, 228) besitzt, die an jeweils gegenüberliegenden Seiten der Achse durch die erste und zweite Gelenkverbindung (226, 222) beabstandet sind; sowie eine Nockenvorrichtung (200) enthält, die mit dem Druckgaskolben verbunden ist und eine erste und zweite Nockenfläche (202, 204) besitzt, um jeweils auf die dritte und vierte Gelenkverbindung (224, 228) zu wirken, um die dritte und vierte Gelenkverbindung (224, 228) im sesentlichen parallel zur Translationsachse des Klammernvorschubs (40) während eines ersten Teils des Arbeitshubs des Druckgaskolbens (64) entsprechend dem Vorschub der Klammer (42) zu stoßen und die dritte und vierte Gelenkverbindung (224, 228) während des restlichen Arbeitshubs des Gasdruckkolbens (64) zueinander zu stoßen, was dem Setzen der Klammer (42) entspricht.

2. Vorrichtung gemäß Anspruch 1, dadurch gekennzeichnet, daß die Arbeit, die vom Gasdruck ausgeführt wird, der am Druckgaskolben (64) während jedes Bewegungsschritts des Kolbens (64) anliegt, zumindest gleich, aber nicht wesentlich größer als jene Arbeit ist, die erforderlich ist, um den zugehörenden schrittweisen Vorschub für das schrittweise Setzen der Klammer (42) hervorzurufen.

3. Vorrichtung gemäß Anspruch 1, dadurch gekennzeichnet, daß sich der mechanische Wirkungsgrad des mechanischen Gelenkgetriebes (70) von einem ersten Wert auf einen zweiten, im wesentlichen unterschiedlichen Wert ändert, wenn die Klammer (42) im wesentlichen vollständig vorgeschoben ist und mit dem Setzen der Klammer (42) gerade begonnen wird.

4. Vorrichtung gemäß Anspruch 1, dadurch gekennzeichnet, daß der mechanische Wirkungsgrad des mechanischen Gelenkgetriebes (70) während des Vorschubs der Klammer (42) einen ersten, im wesentlichen konstanten Wert besitzt und während des Setzens der Klammer (42) einen zweiten, im wesentlichen unterschiedlichen, jedoch im wesentlichen konstanten Wert besitzt.

5. Vorrichtung gemäß Anspruch 1, dadurch gekennzeichnet, daß der Klammernvorschub (40) eine translatorische Bewegung ausführt, um die Klammer (42) vorzuschieben und zu setzen.

6. Vorrichtung gemäß Anspruch 1, dadurch gekennzeichnet, daß sowohl die erste als auch die zweite Nockenfläche (202, 204) einen ersten Teil (206) besitzt, der im wesentlichen senkrecht auf die Translationsachse des Klammernvorschubs steht, um während des ersten Teils des Arbeitshubs des Druckgaskolbens auf die zugehörende Gelenkverbindung zu wirken, sowie einen benachbarten zweiten Teil (208) enthält, der relativ zur Translationsachse des Klammernvorschubs (40) geneigt ist, um während des zweiten Teils des Hubs des Druckgaskolbens (64) auf die zugehörende Gelenkverbindung zu wirken.

7. Vorrichtung gemäß Anspruch 6, dadurch gekennzeichnet, das der zweite Teil (208) einer jeden Nockenfläche (202, 204) mit dem benachbarten ersten Teil (206) einen stumpfen Winkel einschließt.

8. Vorrichtung gemäß Anspruch 1, dadurch gekennzeichnet, daß sie weiters enthält:

eine händisch zu betätigende Steuerung (26);

eine Einrichtung (110, 120, 130), die auf eine momentane Betätigung der händisch zu betätigenden Steuerung (26) anspricht, um normalerweise den Druckgaskolben (64) zu veranlassen, daß er ein vollständiges Arbeitsintervall ein-

schließlich eines Arbeitshubs ausführt, auf den ein Leerhub folgt, mit dem der Kolben (64) in seine Ausgangsstellung zurückkehrt; und

eine Einrichtung (120), die auf die Betätigung der händisch zu betätigenden Steuerung (26) während des Arbeitshubs des Druckgaskolbens (64) anspricht, um den Arbeitshub zu unterbrechen und den Kolben (64) in seine Ausgangsstellung zurückzuführen.

9. Vorrichtung gemäß Anspruch 8, dadurch gekennzeichnet, daß die Einrichtung, die auf die momentane Betätigung der händische zu betätigenden Steuerung anspricht, eine Einrichtung (110) aufweist, um den Beginn eines weiteren Arbeitsintervalls zu verhindern, bis die händisch zu betätigende Steuerung freigegeben wurde und das vorangegangene Arbeitsintervall beendet ist.

10. Vorrichtung gemäß Anspruch 8, dadurch gekennzeichnet, daß die Einrichtung, die auf die momentane Betätigung der händisch zu betätigenden Steuerung anspricht, enthält:

einen bewegbaren Nockenteil (120), der so angebracht ist, daß er sich normalerweise mit dem Druckgaskolben (64) bewegt, und die eine Arbeitshub-Nockenfläche (160) sowie eine Leerhub-Nockenfläche (166) besitzt;

einen Nockenstößel (130), der während eines Arbeitshubs des Druckgaskolbens (64) in die Arbeitshub-Nockenfläche (160) eingreift und während eines Leerhubs des Kolbens (64) in die Leerhub-Nockenfläche (66) eingreift, um den Gasdruck nur dann an den Druckgaskolben (64) anzulegen, wenn der Eingriff mit der Arbeitshub-Nockenfläche (160) erfolgt; und

eine Einrichtung (110), um die Bewegung des bewegbaren Nockenteils (120) so einzuleiten, daß der Nockenstößel (130) in Abhängigkeit von der Betätigung der händisch zu betätigenden Steuerung (26) in die Arbeitshub-Nockenfläche (160) eingreift.

11. Vorrichtung gemäß Anspruch 10, dadurch gekennzeichnet, daß die Einrichtung, die auf die momentane Betätigung der händisch zu betätigenden Steuerung anspricht, weiters enthält:

eine Einrichtung, um zu verhindern daß der bewegbare Nockenteil (120) während des Leerhubs des Druckgaskolbens (64) in seine Ausgangsstellung zurückkehrt, wenn die händisch zu betätigenden Steuerung weiterhin betätigt wird, wodurch verhindert wird, daß ein weiteres Arbeitsintervall ausgelöst wird, bis die händisch zu betätigende Steuerung (26) freigegeben wurde und das vorhergehende Arbeitsintervall vollendet ist.

12. Vorrichtung gemäß Anspruch 11, dadurch gekennzeichnet, daß sie weiters enthält:

eine Einrichtung, die auf die Betätigung der händische zu betätigenden Steuerung während des Arbeitshubs des Druckgaskolbens (64) anspricht, um den Nockenstößel (130) dazu zu bringen, die Arbeitshub-Nockenfläche (160) zu verlassen und in die Leerhub-Nockenfläche (166) einzugreifen, um den Arbeitshub zu unterbrechen und den Kolben (64) in seine Ausgansstellung zurückzubringen.

13. Vorrichtung gemäß Anspruch 11, dadurch gekennzeichnet, daß der Nockenstößel (130) den Gasdruck aus dem Gasdruckkolben (64) abläßt, wenn er nicht mit der Arbeitshub-Nockenfläche (160) in Eingriff steht, wobei der Leerhub des Gasdruckkolbens durch die Kraft einer Rückstellfeder (180) ausgeführt wird.

14. Vorrichtung gemäß Anspruch 1, dadurch gekennzeichnet, daß die vom Druckgaskolben (64) während dessen Arbeitshub durchgeführte Arbeit etwa gleich jener Arbeit ist, die für den Vorschub und das Setzen der Klammer (42) erforderlich ist.

15. Vorrichtung gemäß Anspruch 1, dadurch gekennzeichnet, daß das mechanische Gelenkgetriebe (70) die Bewegung des Druckgaskolbens (64) während des ersten Teils seines Arbeitshubs entsprechend verstärkt, um die Klammer vorzuschieben, und die Kraft des Druckgaskolbens (64) während seines restlichen Arbeitshubs entsprechend verstärkt, um die Klammer (42) zu setzen.

16. Vorrichtung gemäß Anspruch 5, dadurch gekennzeichnet, daß die Nockenflächen (200) ein Joch besitzen, das mit dem Druckgaskolben (64) verbunden ist und sich zum viergliedrigen Gelenkgetriebe (210) öffnet, wobei das Joch eine erste und zweite Endfläche (206) besitzt, die zur Achse des Druckgaskolbens im wesentlichen senkrecht stehen, um während des ersten Teils des Arbeitshubs des Druckgaskolbens (64) auf die dritte bzw. vierte Gelenkverbindung (224, 228) zu wirken, sowie eine dritte und vierte muldenförmige Fläche (208) besitzt, die jeweils neben der ersten und zweiten Endfläche (206) liegen, um während des restlichen Arbeitshubs des Druckgaskolbens (64) auf die dritte bzw. vierte Gelenkverbindung (224, 228) zu wirken.

17. Vorrichtung gemäß jedem der Ansprüche 1 bis 16, dadurch gekennzeichnet, daß sei eine selbständige, mit Druckgas betriebene Halterung (12) ist, um ein Magazin (14), das chirurgische Klammern (42) enthält, zu halten und zu betätigen, wobei die Halterung enthält:

einen Vorrat einer unter Druck stehender pneumatischer Flüssigkeit (50);

einen Druckgaszylinder (62), der mit dem Vorrat einer unter Druck stehenden pneumatischen Flüssigkeit (50) pneumatisch verbunden ist;

einen Druckgaskolben (64), der für eine hin- und hergehende Bewegung im Zylinder (62) angebracht ist; und

das mechanische Gelenkgetriebe (70) zwischen dem Druckgaskolben (64) un dem zu betätigenden Teil des Magazins.

18. Vorrichtung gemäß jedem der Ansprüche 1 bis 16, dadurch gekennzeichnet, daß sie eine selbständige, mit Druckgas betriebene chirurgische Heftvorrichtung ist, die enthält:

einen Vorrat von Druckgas (50) in der Heftvorrichtung;

einen Druckgasantrieb mit einem Zylinder (62) und einem Kolben, der im Zylinder (62) hin- und herbewegbar angebracht ist;

eine Gasleitung (56) einschließlich eines Ven-

tils, um in einem Arbeitshub wahlweise Druckgas vom Gasvorrat (50) zum Druckgasantrieb zu leiten, um den Kolben (64) anzutreiben;

einen Klammernvorschub (40), um die Klammer (42) vorzuschieben und zu setzen; und

das mechanische Gelenkgetriebe (70) zwischen dem Kolben (64) und dem Klammernvorschub (40).

19. Vorrichtung gemäß anspruch 18, dadurch gekennzeichnet, daß der Klammernvorschub (40) relativ zu zumindest einem Teil des Druckgasantriebs drehbar ist.

20. Vorrichtung gemäß Anspruch 19, dadurch gekennzeichnet, daß der Druckgasantrieb ein kreisförmiger Zylinder (62) ist, in dem sich ein Kolben (64) um seine Längsachse relativ zum Druckgasantriebszylinder drehen kann, wobei sich das mechanische Gelenkgetriebe (70) und der Klammernvorschub (40) mit dem Kolben (64) drehen.

21. Vorrichtung gemäß Anspruch 18, dadurch gekennzeichnet, daß der Vorrat (50) von Druckgas ein Gas liefert, dessen Druck kleiner als 70 Gramm pro Quadratzentimenter ist.

22. Vorrichtung gemäß Anspruch 18, dadurch gekennzeichnet, daß der Vorrat an Druckgas (50) eine Überdruckablaßeinrichtung aufweist, um das Druckgas aus dem Druckgasvorrat automatisch abzulassen, wenn der Gasdruck im Druckgasvorrat einen vorgegebenen Schwellwert überschreitet, der unterhalb jenes Drucks liegt, bei dem der Druckgasvorrat explodieren würde.

23. Vorrichtung gemäß Anspruch 22, dadurch gekennzeichnet, daß der Druckgasvorrat ein Behälter (50) mit einem Wandteil (280) ist, der normalerweise konkav nach innen ausgebildet ist und sich nach außen verformt, wenn der Druck des Gases im Behälter den vorgegebenen Schwellwert überschreitet, und wobei die Vorrichtung weiters eine Dorneinrichtung (290, 292) enthält, die neben der normalerweise konkav nach innen ausgebildeten Behälterwand (280) angeordnet ist, um den Behälterwandteil zu durchstoßen und das Gas abzulassen, wenn sich der Wandteil nach außen verformt.

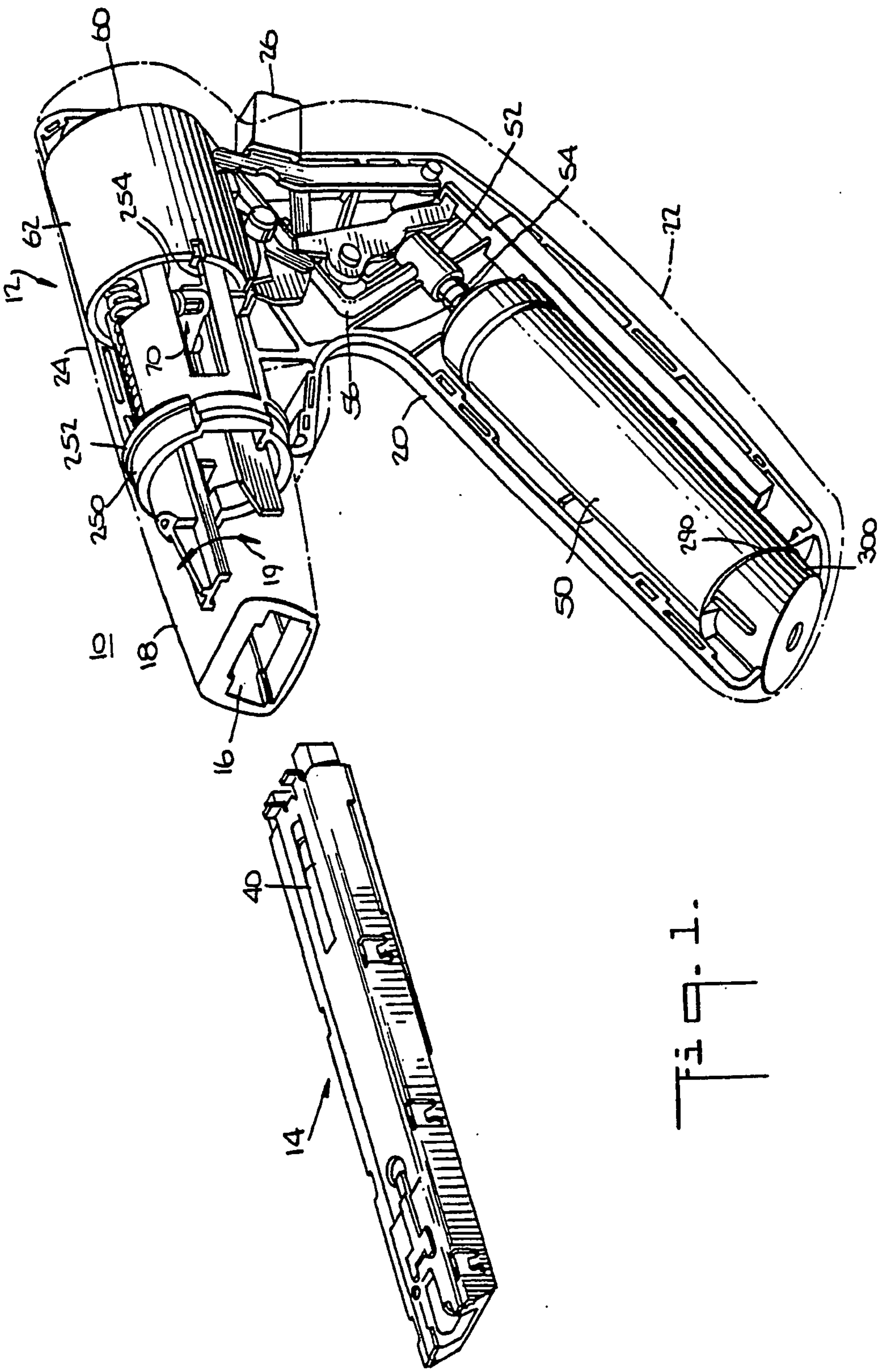
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Fig. 1.

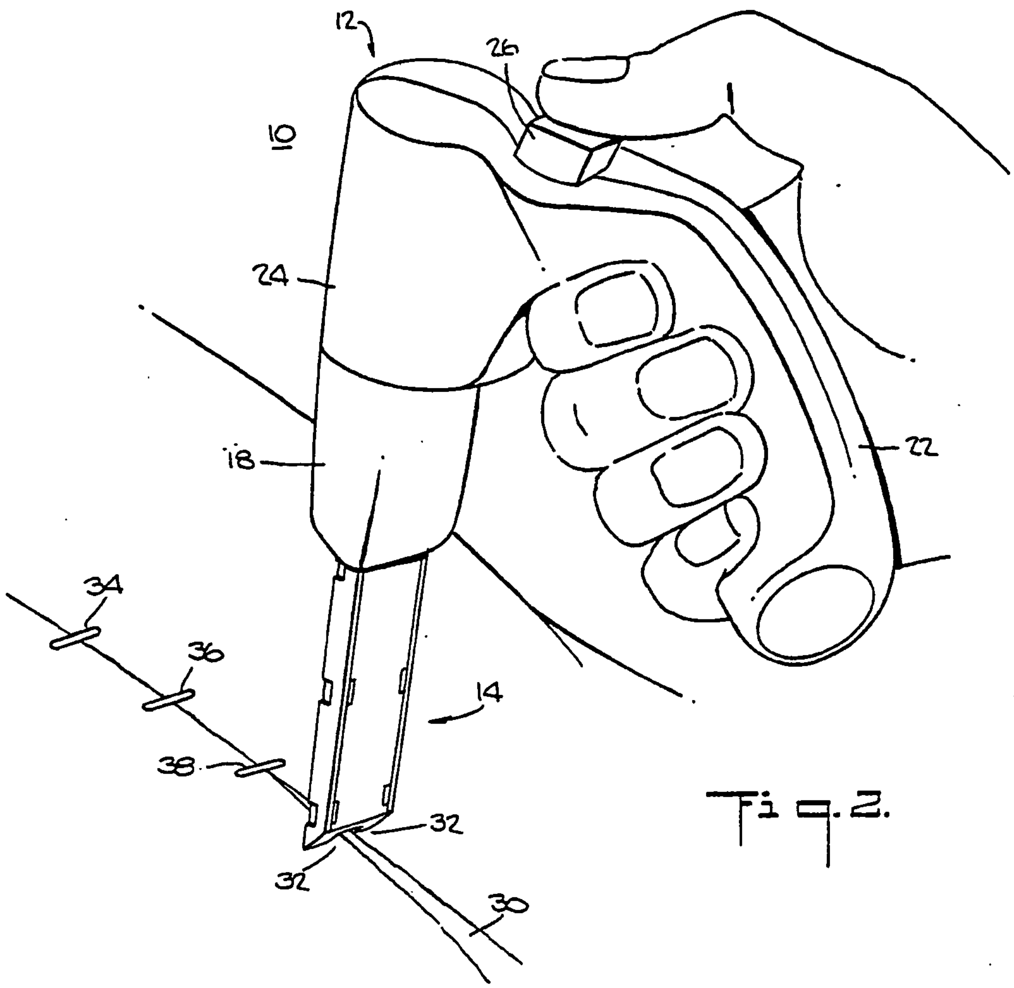
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Fig.2.

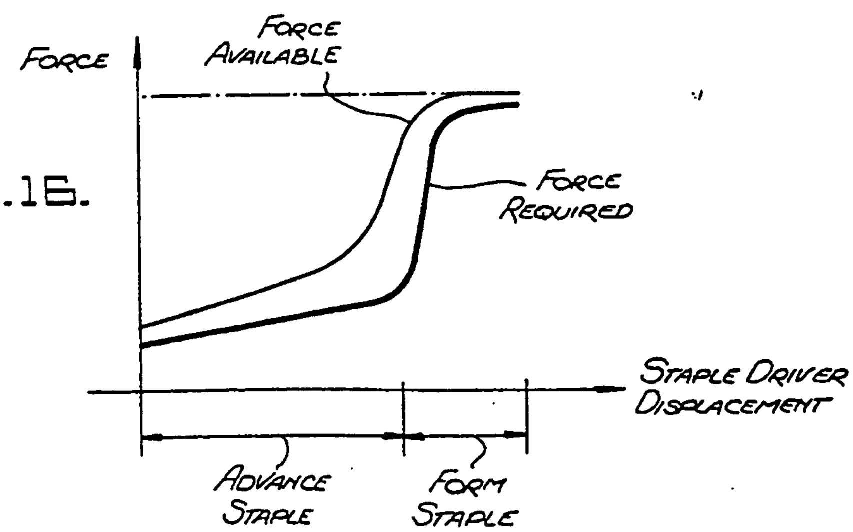
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Fig.16.

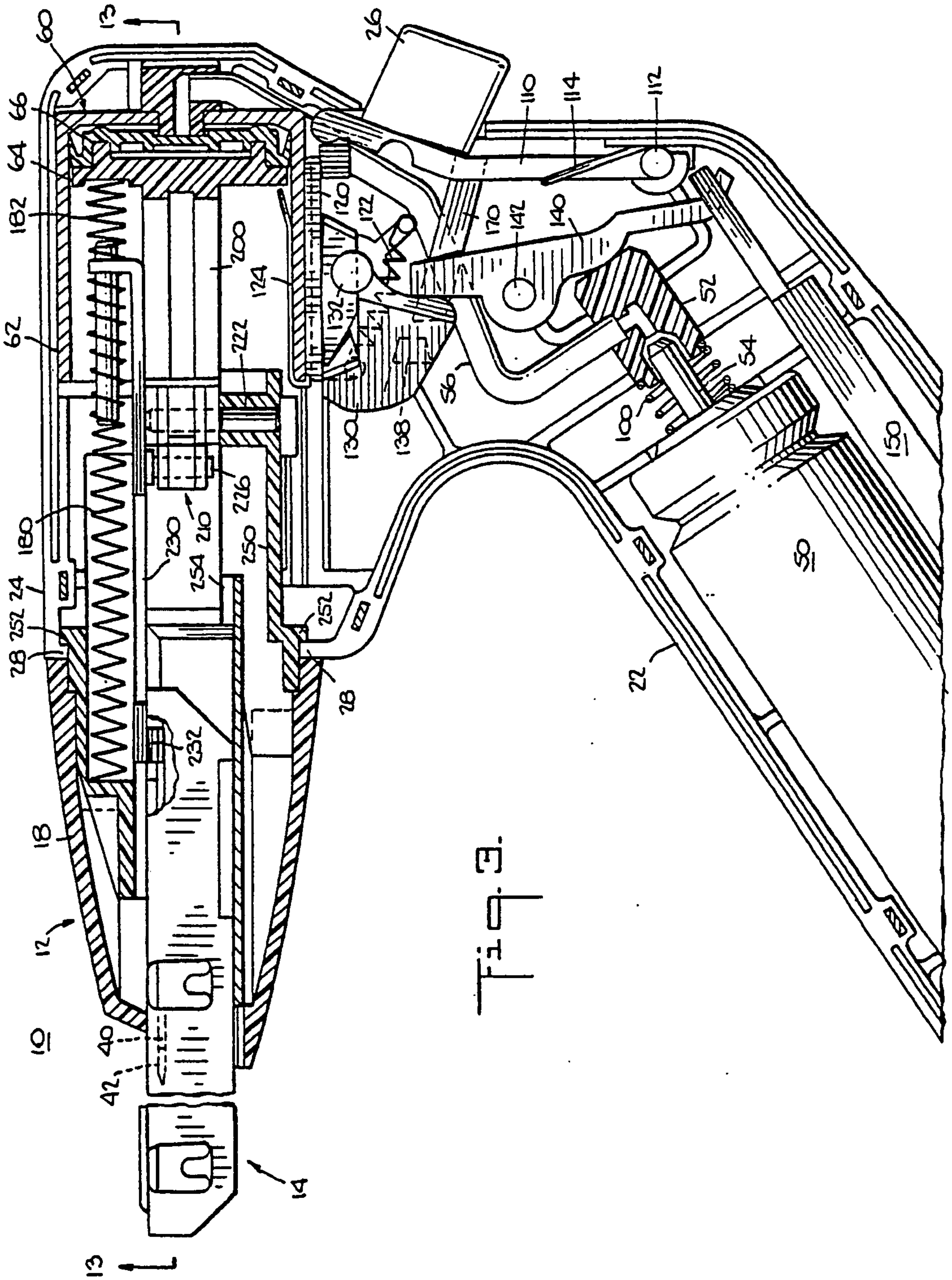

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Fig. 3

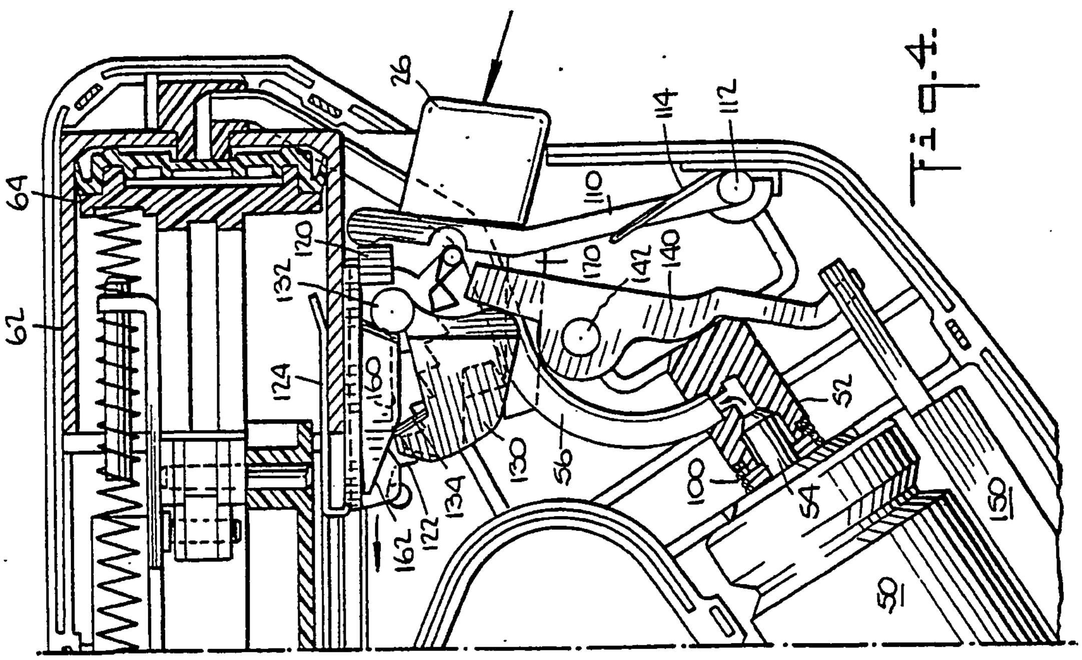
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Fig.4.

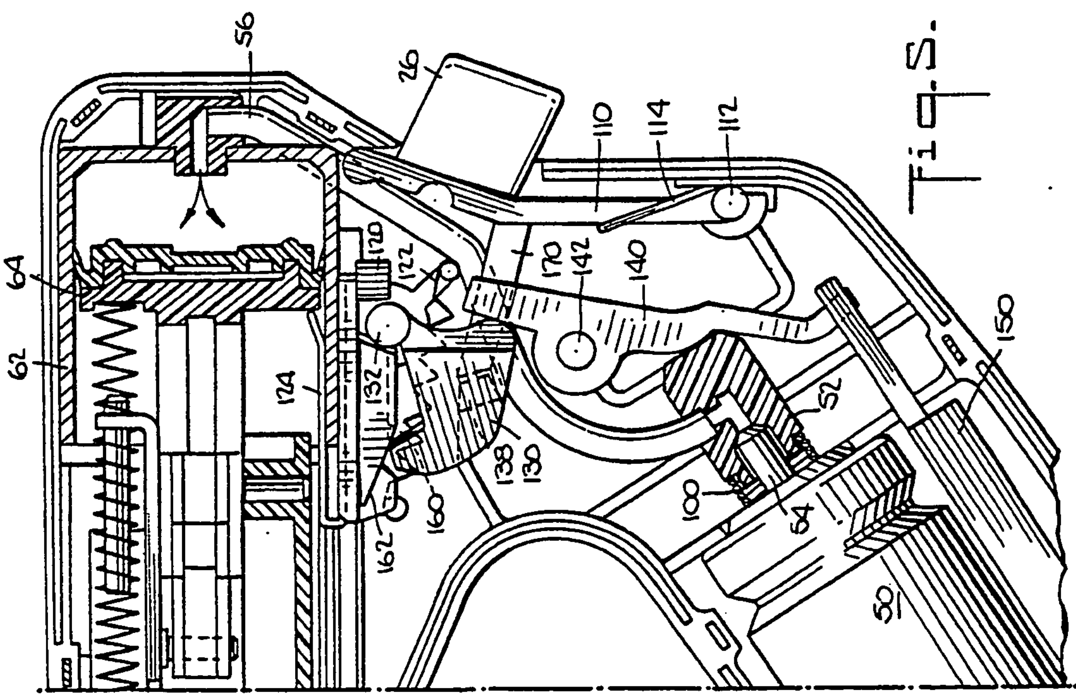
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Fig.5.

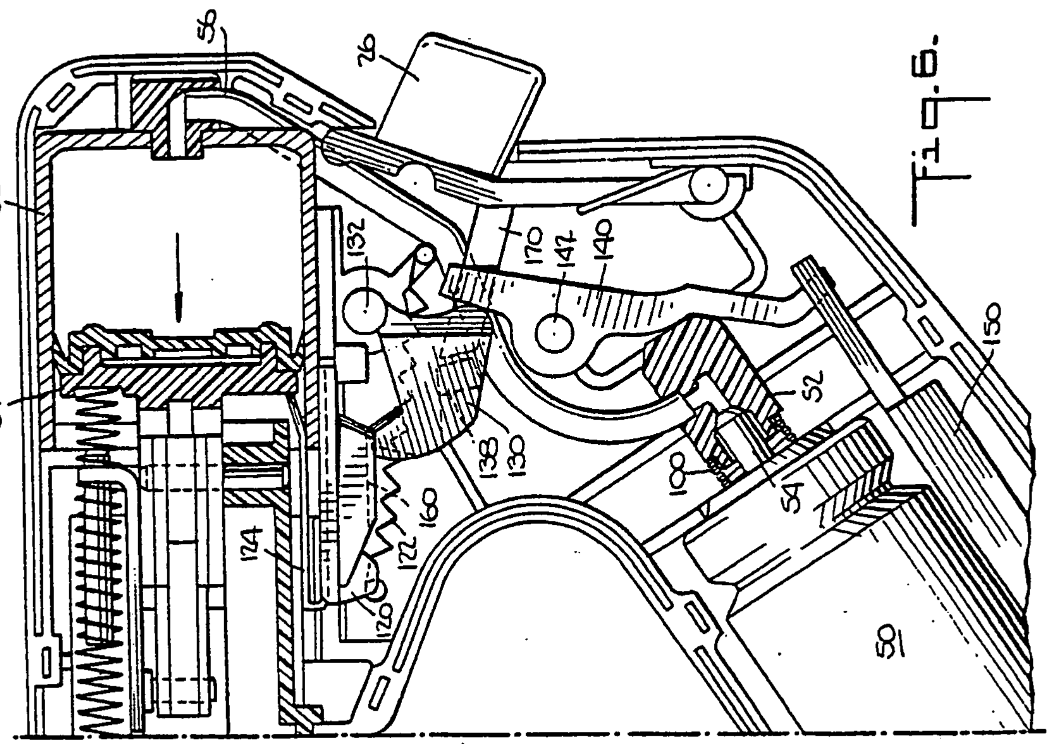
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Fig.6.

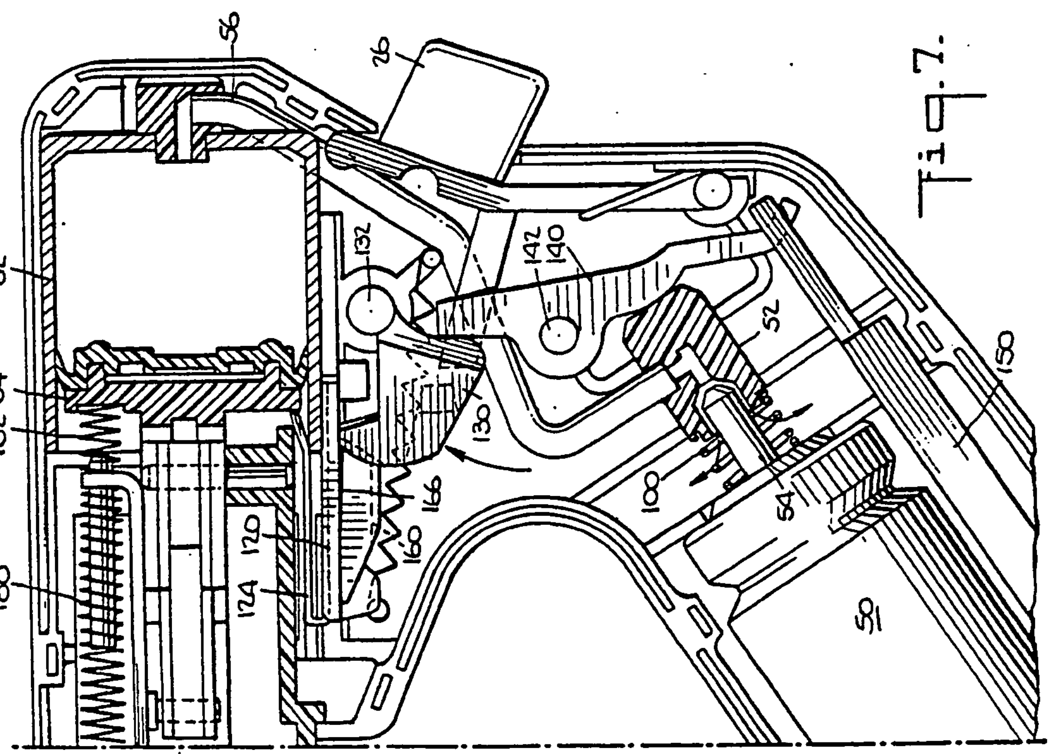
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Fig.7.

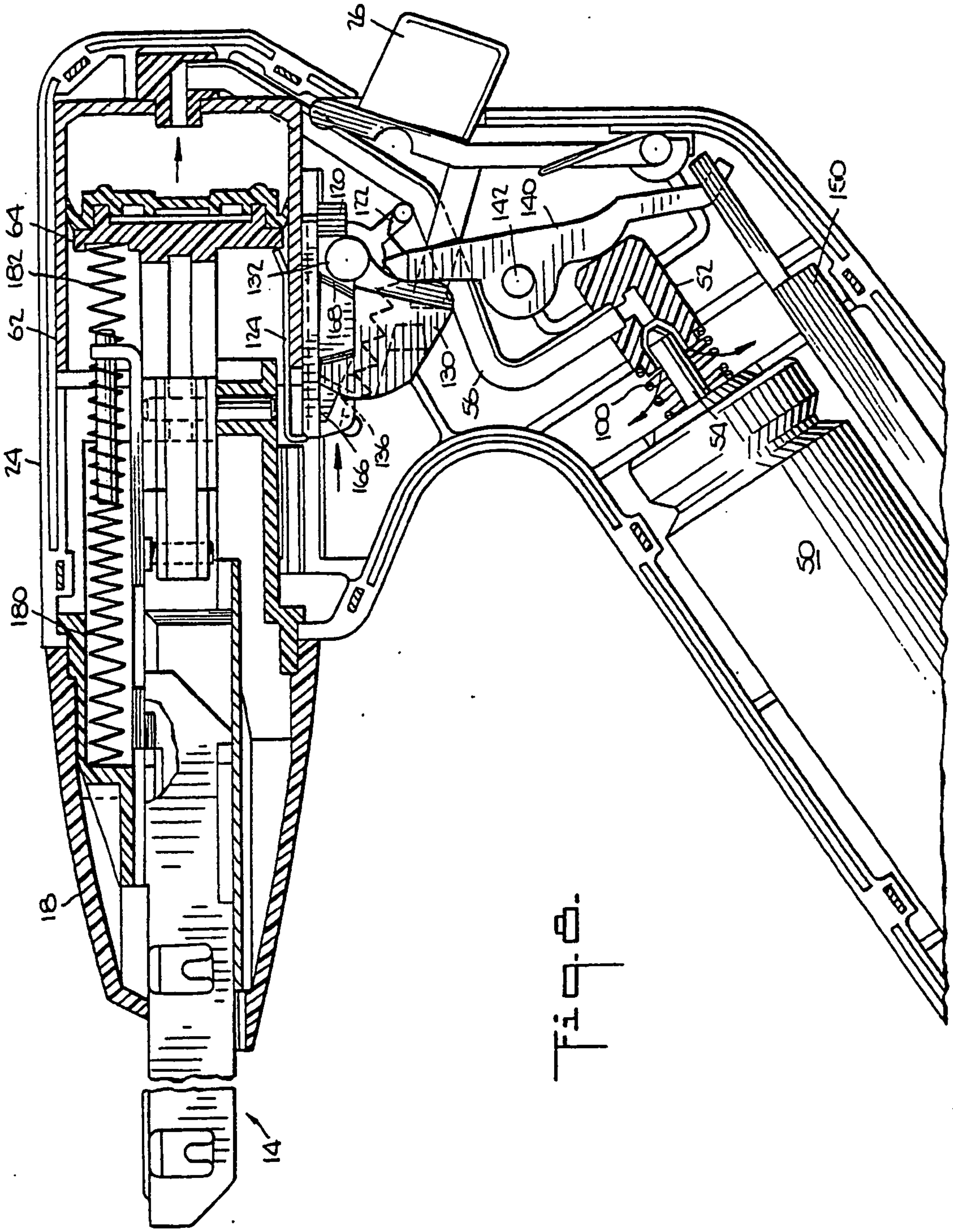
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Fig. 8

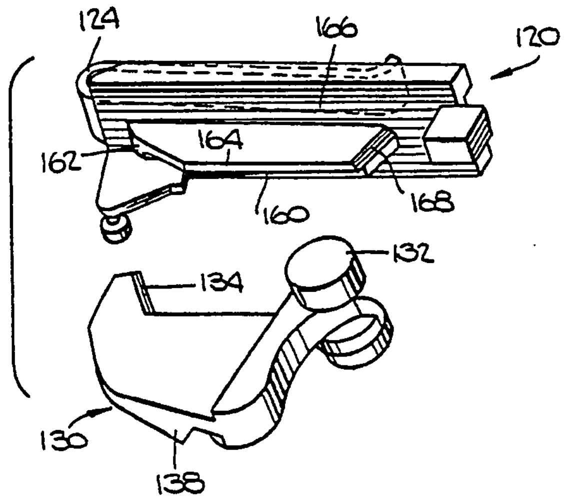
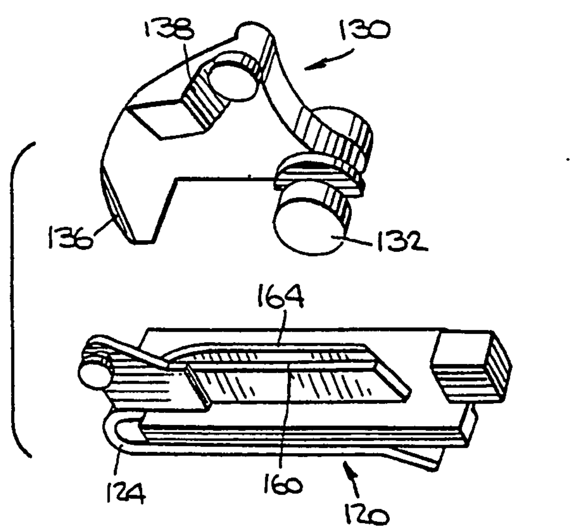


Fig. 9.

Fig. 10.



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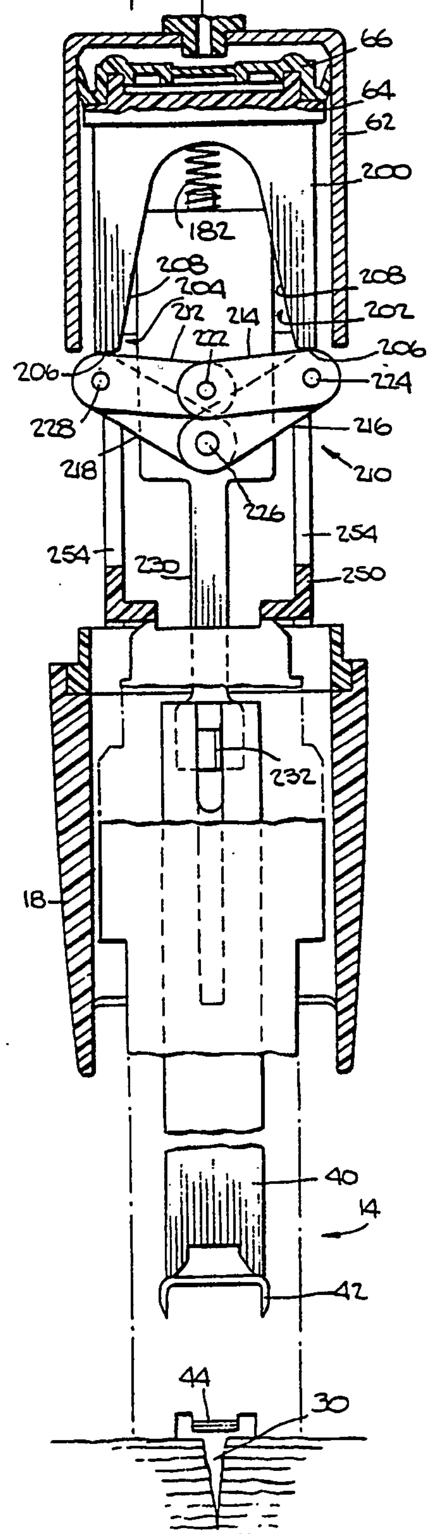

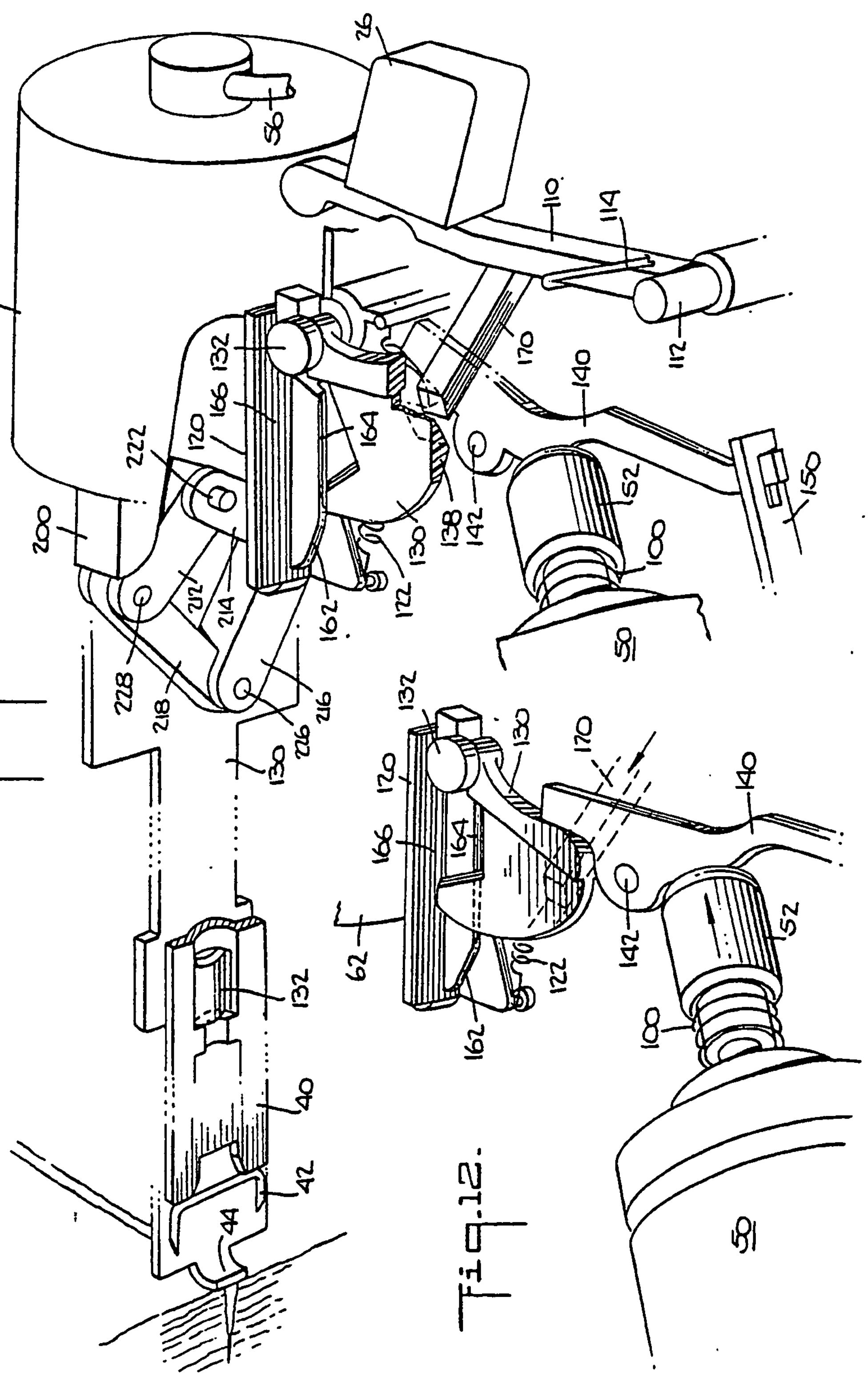
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Fig.11.

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Fig.12.

Fig.14.

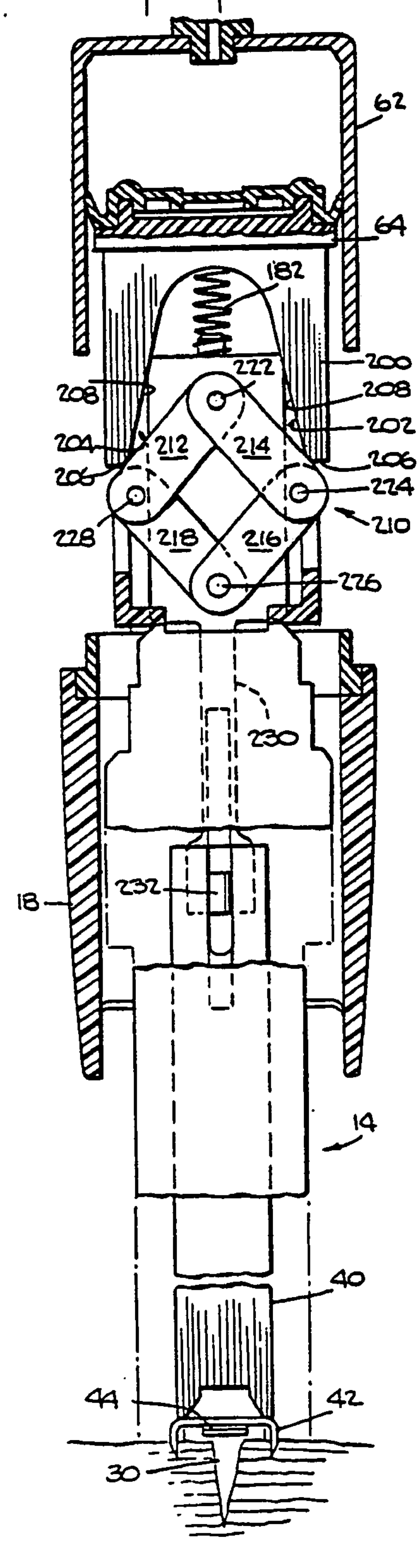
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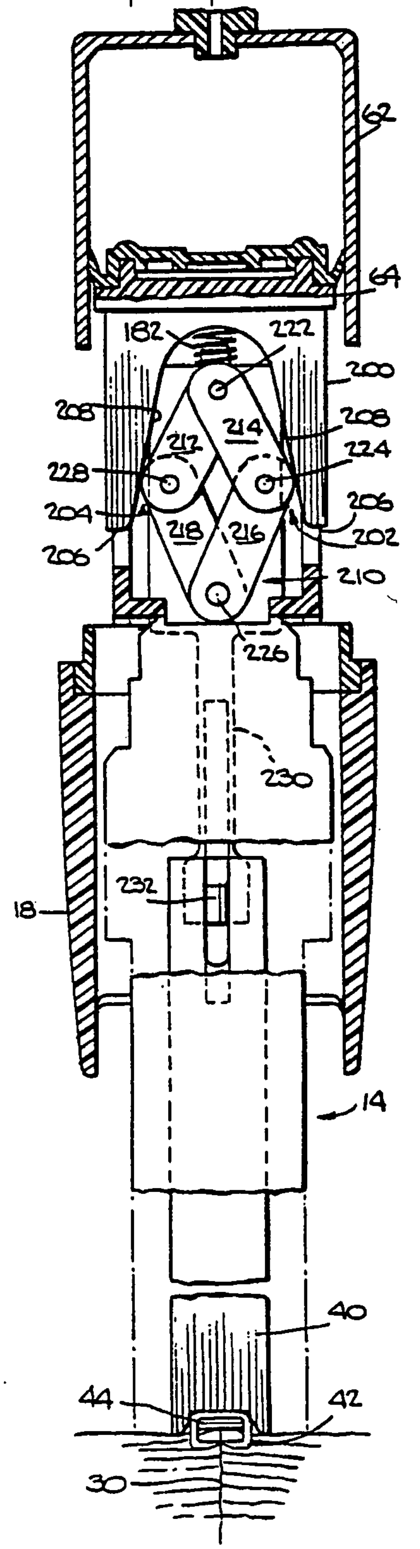
Fig.15.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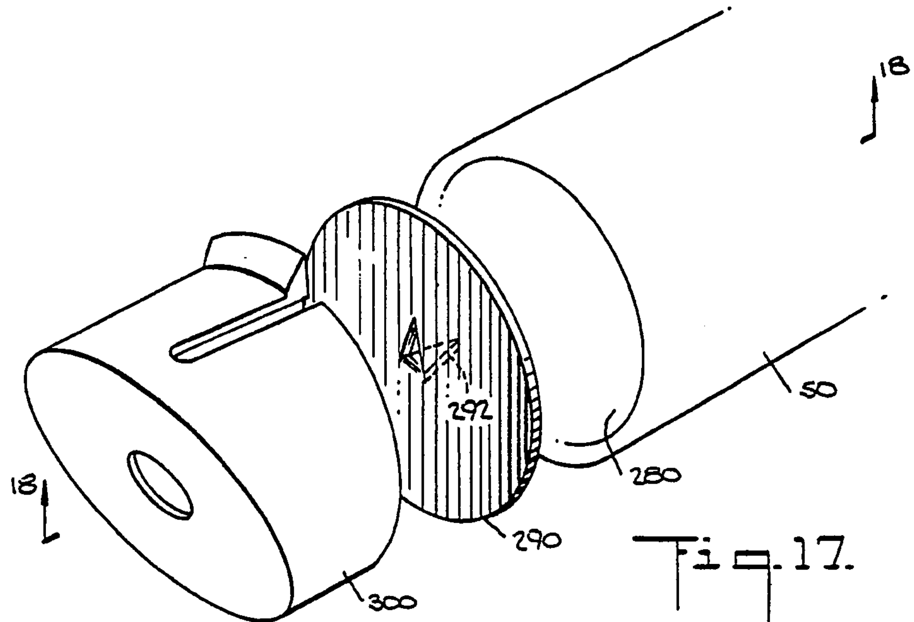

Fig. 17.

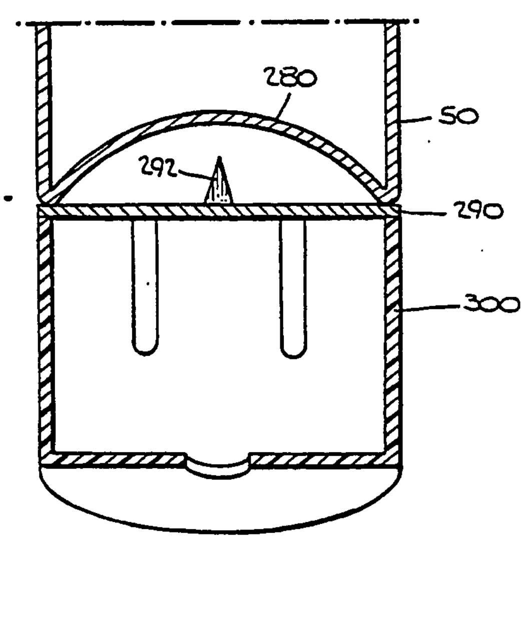

Fig. 18.

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